University of Fort Hare
Together in Excellence

A MOBILE BASED CONTROL SYSTEM FOR SMART HOMES

BY
Tshimanga Danny Kazadi
(201414598)

University of Fort Hare
Together in Excellence

Submitted in fulfilment of the requirements for the degree of
Masters in Computer Science

Faculty of Science and Agriculture

University of Fort Hare, Eastern Cape

SUPERVISOR: Professor. K Sibanda

Date 18 March 2022

ABSTRACT

A Smart Home Control System can provide a secure home, convenience, comfort, and interactivity of life in a particular home. The system can enable the automatic controlling of a house via a Smart Phone. These systems are becoming vital and widely used in homes to improve conditions of life. Most commercial home automation systems are expensive and their maintenance would require experts who understand the underlying implementation of the systems. This study developed a mobile-based home automation system prototype. The system was developed using the waterfall model methodology. To evaluate the developed system, the study used a simulation method. Ten trials were conducted to determine the performance of the implemented system. The mean time to failure was used to evaluate the system' reliability. The system's performance analysis revealed that the developed system performed better than the two other approaches; the Bluetooth and ZigBee. The developed system showed a 0% error, while the Bluetooth had 8% error and ZigBee 6% error. The reliability results showed the average lifespan of assets in the system before they could fail. Knowing the lifespan of an asset before it fails can help in reducing downtime of the system by planning or scheduling maintenance and develop an improved maintenance strategy.

University of Fort Hare

Keywords: *Smart Home Automation System, Mobile based control system, Smart Home, Internet of Things, Arduino, Mobile App, ESP8266, Automation System, Wi-Fi. Reliability, Performance analysis, AI, Machine Learning, Deep Learning, Reinforcement Learning, Deep Reinforcement Learning*

Copyright © 2021 University of Fort Hare

Declaration on plagiarism

I, TSHIMANGA DANNY KAZADI, student number 201414598, hereby declare that I am fully aware of the University of Fort Hare's policy on plagiarism and I have taken every precaution to comply with the regulations.

Signature: 

Date: 7 July 2021

University of Fort Hare
Together in Excellence

Declaration on ethical clearance

I, TSHIMANGA DANNY KAZADI, student number 201414598, hereby declare that I am fully aware of the University of Fort Hare's policy on research ethics and I have taken every precaution to comply with the regulations. I confirm that my research constitutes an exemption to Rule G17.6.10.5 and an ethical certificate with a reference number is not required.

Signature:

Date:7 July 2021

University of Fort Hare
Together in Excellence

ACKNOWLEDGEMENTS

First, I would like to give glory to the one and only one Great and Mighty God, for His grace and mercy upon my life, to the Holy Spirit for wisdom, and joy given to me through Him, and to my Lord and Saviour for the strength given to me through Him. Through Him, I managed to finish my Master’s degree. Truly I quote, “I can do all things through Christ who strengthens Me”- Philippians 4:13. A special thank you to my parents Samuel and Marie Mwamba, for their counsels, prayers, and encouragement I thank and praise God for your lives. To my biological family, brothers, sisters, nieces, and nephews, thank you for your prayers and encouragement. To my brothers and sisters in low, thank you for your support. To my VPM family, to my Pastors Boafo and Rose, I thank God for you and I say thank you for your spiritual support and guidance.

It is with great thanks that I acknowledge my supervisor Professor K Sibanda who tirelessly encourage, guide, and made this research a triumph, for his positive attitude, thoughtful and helpful ideas, I say thank you, and may God keeps on increasing you. To my classmate CSC class of 2020, I say thank you for the smile you always put on my face. Lastly to my HOD Mr. Siyabulela Dyakalashe who gave me this opportunity to do my master’s degree, thank you for your good heart.

University of Fort Hare
Together in Excellence

DEDICATION

To my late Father for his honest earning living and his encouragement and support to always believe and have confidence in myself and for the greatest gift a father can give to his Son, I mansion, JESUS - CHRIST.

To my Mother, for her wisdom and guidance in my life. For being the angel and guardian over my spiritual life for showing me the right path.

To my brothers and sisters for been my reference of life and first teacher.

University of Fort Hare
Together in Excellence

CONTENTS

University of Fort Hare
Together in Excellence

University of Fort Hare
Together in Excellence

University of Fort Hare
Together in Excellence

University of Fort Hare
Together in Excellence

LIST OF FIGURES

University of Fort Hare
Together in Excellence

University of Fort Hare
Together in Excellence

LIST OF TABLES

University of Fort Hare
Together in Excellence

ACRONYMS AND ABBREVIATIONS

IoT	Internet of Things
UID	Unique Identifiers
VT	Virtual Terminal
VTC	Virtual Terminal Command
RFID	Radio Frequency ID
P&G	Protect and Gamble
MEMS	Microelectromechanical Systems
OT	Operational Technology
IT	Information Technology
M2M	Machine-to-machine
IEEE	Electrical and Electronic Engineers
WLAN	Wireless Local Area Network
WPA2	Wi-Fi Protected Access 2
PAN	Personal Area Networks
FHSS	Frequency Hopping Spread Spectrum
IP	Internet Protocol
RF	Radio Frequency
Wi-Fi	Wireless Fidelity
BLE	Bluetooth Low Energy
PWM	Pulse Width Modulation
ICSP	In-Circuit Serial Programming
SoC	System on Chip
SDK	Software Development Kits
ESCP	Espressif Systems Smart Connectivity Platform
GND	Ground
VCC	
NC	Normally Closed
TX	Transmit
TXD	Transmit Date
RX	Receive
RXD	Receive Data
NO	Normally Open

University of Fort Hare

MANETS	Mobile ad hoc networks
FHSS	Frequency-hopping spread spectrum
ICSP	In-circuit serial programming
PWM	Pulse Width Modulation
UI	User Interface
AMApp	Android Mobile Application
ML	Machine Learning
DL	Deep Learning
RL	Reinforcement Learning
CNN	Convolutional neural network
HMS	Home Management System
DRL	Deep Reinforcement Learning

University of Fort Hare
Together in Excellence

CHAPTER 1: INTRODUCTION

The Internet of things (IoT) is a system that brings together numerous devices that may include, mobile phones, washing machines, geysers, wearables and many other devices which are embedded with unique identifiers (UIDs) and have abilities to convey data without the help of human-to-human or human-to-computer interaction over the network [2]. IoT has become a buzzword in almost all levels of society and more so, among the research community. This is not only because it is a relatively new technology, but also because of its ability to offer a seamless platform for automation of human activities, be it at home or at work places. Home automation is the pulling together of the management of home appliances and amenities through a centralised point. This has many advantages, for example managing the switching on and off the lights in the house, switching on and off air conditioners, somethings that help in saving electricity. Electricity is now very expensive, therefore employing energy saving mechanisms helps by saving costs. Home automation technologies have led to the emergency of smart homes. Smart homes have become a more comfortable place even for the aged and the disabled. According to Stats SA from 2011 population census, 7.5% of people in South Africa are living with disability [1]. This number obviously has increased by now. Smart homes come as a relief to this section of the society as home automation technology provides inclusiveness to the aged and the physically challenged. Home automation improves lives by allowing the aged and the disabled people navigate through challenges that come with age and disability. In pursuant of viable home automation systems, a number of works that propose home automation solutions have emerged. For example, (M. Yan and H. Shi, 2013) and (R. Piyare and S. R. Lee, 2013) proposed a home automation system that is based on Bluetooth. The system based on Bluetooth is however not suitable for IoT ecosystem as it does not provide Internet controllability. This system also inherits Bluetooth's short distance limitation. There are a number of other systems for example ZigBee and Wi-Fi, as connectivity options. However, most of these systems are still undergoing refinement and improvement. Therefore, there is still a lot of room on developing and experimenting with home automation systems. This study joins other efforts that are involved in developing and testing of home automation systems. The purpose of this chapter is to lay down the focus of this study. It gives the study's motivation, problem statement, research questions, objectives and the research report outline.

University of Fort Hare
Together in Excellence

1.1 Problem Satement

Home automation systems are becoming an essential part of human lives especially among the socio-economic hierarchies, the middle class and upper class. These systems enable remote switching on/off lights, geysers air-condition and other things like television and music. This brings about convenience to the users, as the switching on/off of gadgets is centralised. Home automation also saves energy in the house through automatic switching off idle gadgets. Despite all the benefits of home automation systems, they are still beyond the reach of many especially in developing economies. Most commercial home automation systems are expensive and their maintenance would require experts who understand the underlying implementation of the systems. This calls for concerted efforts to develop inexpensive systems using open-source tools. With the wide use of android phones and having many homes with computerised gadgets, it makes sense to develop inexpensive android-based home automation systems that can easily be deployable. This study developed an easy to control home automation system prototype and tested its efficiency and reliability.

1.2 Research Questions

IN LUMINE TUO VIDEBIMUS LUMEN
University of Fort Hare
Together in Excellence

1. What techniques are used for the development of smart home systems?
2. What are communication technologies used with smart home systems?
3. How can we design and implement a smart home mobile base control system using Arduino Uno microcontroller?
4. How is the performance of the developed home automation system?

1.3 Research Objectives

The aim of the research is to build and analyse the reliability of a mobile-based home automation system.

1.4 objectives include:

1. To determine the techniques used for the development of smart home control systems.
2. To identify technologies used for implementing home automation systems.
3. To design and implement a home automation system based on Android.
4. To evaluate the performance and reliability of the developed mobile-based smart home control system.

1.4 Research Methodology

This study used three approaches to achieve the objectives of the study. Firstly, for reviewing literature, the study used systematic literature review methodology. In particular, the study used the meta-synthesis variant of systematic literature review. For implementation, the study used the waterfall model. The waterfall model describes the development process as a linear, progressive process, analysis, design, execution, verification and maintenance. Accordingly, any phase of the development can only begin once the previous stage has been completed. For system evaluation, the study applied simulation methodology.

1.5 Contribution

To build a mobile-based control home automation system by using open-source tools, analyse the performance and reliability of the system is the significance of this research. The study' literature review also contributes to the body of knowledge. The system's reliability analysis results give insights for companies for system' maintenance strategies.

1.6 Research Outline

University of Fort Hare
Together in Excellence

The remainder of this dissertation is structured as follows:

Chapter 2: This chapter discusses vital concepts in developing smart home systems and also reviews literature related to this study. Furthermore, the chapter discusses the following most commonly used wireless protocols; the Wireless Fidelity, Bluetooth, ZigBee.

Chapter 3: This chapter discusses the methods and procedures used in the study.

Chapter 4: This chapter discusses the proposed system, components used to design the system, implementation stages and techniques used in the development of the system.

Chapter 5: This chapter presents the system implementation and results.

Chapter 6: As the last chapter, it gives the conclusion of the study as well as the future works.

CHAPTER 2: THEORETICAL BACKGROUND

2.1 Introduction

This chapter answers the first two research questions stated in chapter one. The first question is: What techniques are used for the development of smart home systems? And the second question is: What are communication technologies used with smart home systems? The chapter discuses all important concepts that one needs to comprehend in developing smart home systems. The chapter also presents an explicit literature review surrounding technologies and those protocols that smart homes are most likely to use. The chapter is structured as follows: a literature review is presented in section 2.2. an overview of smart homes is presented in section 2.3. section 2.4 reviews AI and Machine Learning. The Internet of Things is briefly discussed in section 2.5. A discussion of wireless communication protocols and most frequently used wireless protocols in smart homes is presented in section 2.6, including Bluetooth, Wi-Fi, and ZigBee, as well as why they are important for smart homes. Section 2.6 concludes the chapter.

2.2 Literature review

IN LUMINE TUO VIDEBIMUS LUMEN
University of Fort Hare
Together in Excellence

The overall approach used for this study's literature as mentioned earlier, the study used the systematic literature review method. In particular, the study applied the meta-synthesis category. Using meta-synthesis, the study evaluated and interpreted the findings of many related works. The search for relevant articles was conducted using Academia, Research gate, google scholar, IEEE, and IEEE Xplore. The search period was from May 2019 to August 2019.

All the papers containing the terms "smart home", "smart house", "analysis method", "efficiency", "reliability", "internet of things", "control system", "mobile-based control system", "control system using Wi-Fi", "Arduino", "microcontroller", "esp8266", "Wi-Fi or Bluetooth or ZigBee" and "wireless technology" were identified. A total of 3028 articles were found. An additional search was done to find articles related to methods used in determining the reliability and efficiency of the system. Fifteen conceptual articles and books were found. Articles considered were from the year 2000 up to 2019.

Afterward, irrelevant papers were discarded, these included the following:

- Duplicates papers or articles.

- Non-English articles.
- Non-Smart House articles.

2.3 Smart Home

The term Smart home also refers to home automation systems, which are considered a large part of modern home automation that provides residents with convenient, comfort, safety, and energy-efficient [20]. A smart home is a system of technology that facilitates the automation of electrical and electronic devices within a home. It is composed of software and hardware technologies that give the ability to control or manage appliances in homes. Smart home systems provide security, energy efficiency, comfort, and convenience to homeowners [21][22]. Home automation system helps in controlling devices in our daily activities and makes it easy for users. Figure 2.1 is a typical example of a home automation network.

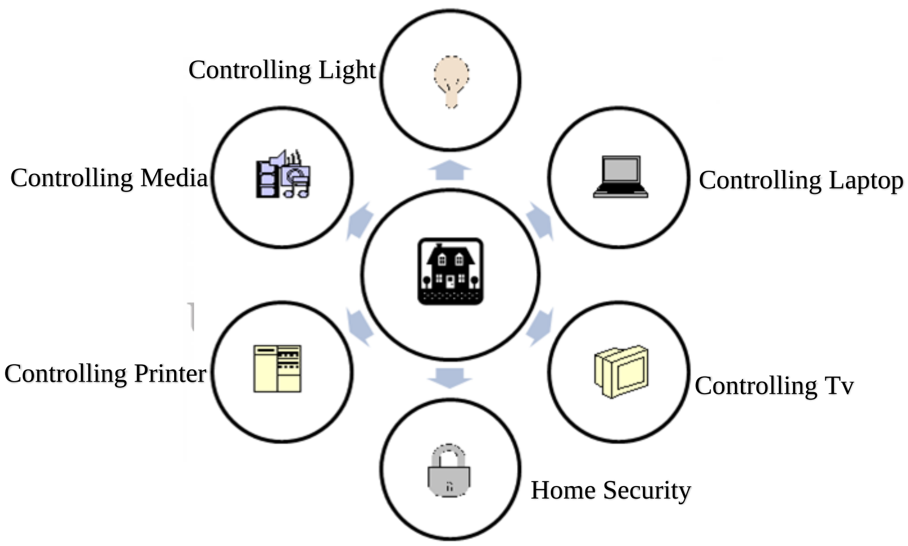


Figure 2-1 Smart Home Network

In modern days, "Smart" which also means intelligence is associated with energy efficiency in houses. Consequently, it is responsible for managing energy in home systems. The system has an objective of making the best use of energy efficiency in residential buildings and remotely monitoring home appliances to minimize and Increase energy efficiency, as well as produce and store energy [23].

Smart homes can be programmed to turn on or off home gadgets and it can operate based on motion detection. As a result, basic and everyday household tasks take less time and effort [23] [24].

Smart Homes offer advantages like [20][23]:

- Savings: Water and energy consumption are reduced for connected devices such as thermostats, lights, heaters, electricity monitoring, etc.… in smart homes.
- Control: Using mobile application, appliances such as fridges, doors, and cameras can be controlled remotely within a home as well as at a different location.
- Convenience: An automated room lights that turn on, a door opening as we approach it, could be conveniences a smart home can offer. With smart locks, we don't need to stay home or give out keys, because certain individuals can have access at certain times by using smart locks. An Internet-enabled doorbell can allow us to do the same wherever we are. Sensors can tell us when our refrigerator is low on milk, and Internet-connected refrigerators can tell us when our milk is running low.
- Security: A home can monitor its video feed, smoke alarms, and motion-activated sensors using a Wi-Fi connection. The system can also send alerts to remote locations.
- Safety: Sensor technology that detects leaks, moisture levels, motions, and other possible worries around us. These technologies can help in preventing misfortunes since there is an interrupted direct communication with homeowners, regardless of the location.

University of Fort Hare
Together in Excellence

People's demand for resources grows steadily as their numbers increase on earth. Efficiency must be improved in the use of food, water, and energy supplies for communities to benefit from their living spaces. Since the Industrial Revolution and right up to the end of World War II, people have used these needs to develop useful inventions and create new technologies. Production alone isn't enough to sustain daily life [51]. Both communications of information and transportation of goods are essential in sustaining daily life. As a result of the communication and transportation needs of people living during these times, several inventions emerged that met these needs, such as the steam engine, the telegraph, the telephone, the first plan, and the first car [51].

A significant number of the inventions mentioned above were proven unsuitable for daily use over time, forcing product development to take center stage. Consequently, other devices, such as 2vacuum cleaners, refrigerator, electronic television, electronic programmable computer, and so many other devices, are invented to increase comfort and usability under the circumstances of the time. It was initially perceived that these inventions were useful for everyday life and that they made housework easier rather than doing it manually. Nevertheless, it has been noted that with the rapid development of industrialization, the inventions above were not at the scale necessary to meet the needs of billions of people [51]. Therefore, people dreamed of developing more advanced or "smarter" systems in their homes, and work spaces to be able to complete all complex tasks without having to exert any extra effort.

Observation of the modern world reveals that humans are surrounded by intelligent systems. Smart systems can communicate with people without them even realizing it, whether it's recommending movies, giving stock advice with the most relevant search, displaying the best products, or giving driving directions with the shortest route. Thus, the application of Machine Learning and Artificial Intelligence technology in intelligent systems, makes life simpler [51].

The term Artificial Intelligence (AI) is a system that enables machines to become more intelligent. The system can grasp, learn, make decisions, and take rational actions to achieve its objective by utilizing methods such as machine learning, deep learning, and reinforcement learning techniques with a wide-range of data set [51].

AI can be used to perform specific tasks and used in many different ways, from medical diagnostics to agriculture or education to electronic commerce platforms. Numerous uses exist for AI. The review will, however, focus mainly on the use of artificial intelligence applications in smart homes.

University of Fort Hare
Together in Excellence

- AI in the energy industry: As the demand for mechanization increases, efficiency increases remain low, and people's energy usage is changing dramatically, the world's energy industry faces some significant challenges. Before the advent of renewable energy resources, fossil fuels were one of the most widely used sources. The improper use of non-renewable fuels such as coal, oil, and natural gas inevitably leads to environmental pollution as well as inefficient use of these fuels. Due to this, people today are switching to "cleaner" and more efficient energy sources than fossil fuels [51]. Despite the idea of using “energy transformation” for every device and system in existence, it has not been possible due to their very nature. Thus, this has resulted in humans saving energy. Even though most people nowadays spend most of their time outdoors, yet the time spent indoors is considerably high. Consequently, questions about home energy consumption are raised leading to the usage of AI in homes which is a potential solution to increase energy savings in smart homes. Using artificial intelligence (AI) in Home Management Systems (HMS), combined with machine learning, the movements and behaviours of the user are recognised and illegal behaviours are detected based on the collected data. Thus, smart systems that are using

AI technologies can determine the ideal amount of energy to spend on a specific device [51].

- AI in agriculture: Today, many factors are contributing to the difficulty of obtaining "quality" food, including the high number of people that need food, increasing amounts of waste, damage to agricultural lands, and unplanned construction on fertile land. As a result, the use of "smart farming practices" has become essential to the survival of humankind. Using artificial intelligence in this area, it is possible to control plant growth parameters, such as time and nutrients. Consequently, farms can produce more efficiently and faster. Various artificial intelligence techniques such as modeling, greenhouse automation, optimisation, and simulation, can be used to obtain advancements in this field [51][52].
- AI in water supply: Although much of the earth is covered with water, water must be used wisely to prevent water scarcities in the near future. Due to the fact that people spend a significant amount of time at home, it is reasonable to assume that household water consumption is also high and can be somewhat rationed. Consequently, many artificial intelligence-based systems for the purpose of water-saving are developed in this field. A basic function of these systems is to create statistical data by monitoring the amount of water used 24/7, cutting off water flow, and notifying users when there is a leak. With the rapid advancement of artificial intelligence, it appears that the use of these AI in homes will skyrocket in the next years [51][32].

University of Fort Hare
Together in Excellence

2.4 Machine Learning

Machine learning (ML) focuses on the method of teaching computer systems to predict precise outcomes using available data. Using Machine Learning, Systems have abilities to automatically learn and improve from predictions without being explicitly programmed [53]. As illustrated in Figure 2-2, Machine Learning is part of Deep Learning (DL). Therefore, artificial intelligence includes both machine learning and deep learning. This learning technique uses algorithms developed to take input data and estimate the outputs. Each time new data is added, the output data is updated according to statistical analysis. Through machine learning, algorithms learn from their training, and processes can be optimized and resources allocated more efficiently. Thus, AI applications can improve themselves due to increasing experiences. The accuracy of the algorithm increases as the number and size of the training set increase. With larger data sets, known variables enable the software to predict more accurately when it is faced with a set of unknown variables. The algorithm learns the correct and incorrect decisions through feedback loops. When these factors are combined, the software becomes more capable and accurate than algorithmic procedures that are manually programmed. With enough training data being fed into an algorithm, Machine Learning can enable the algorithm to outperform any human at the same task. [51][54].

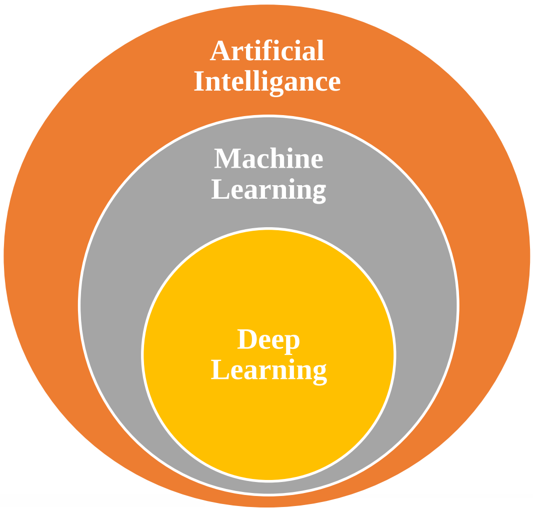


Figure 2-2 The relationship between AI, ML, DL

A great example application of Machine Learning In the healthcare industry will be IBM's Watson Health. Watson Health is IBM's dedicated health division that was formed to bring the benefits of artificial intelligence to healthcare stakeholders like payers and providers. All cancer diagnosis and treatment information available in any language was provided to Watson Health to give a precise and proper solution to any request. To train these programs, subsequent surgeries were used. Consequently, Machine Learning can be used in the following areas: Decision Making, Classification, and Prediction, as well as Diagnosis [51].

University of Fort Hare
Together in Excellence

Supervised Learning, Unsupervised Learning, Reinforcement Learning, Deep Learning, Deep Reinforcement Learning are some of the various types of Machine Learning.

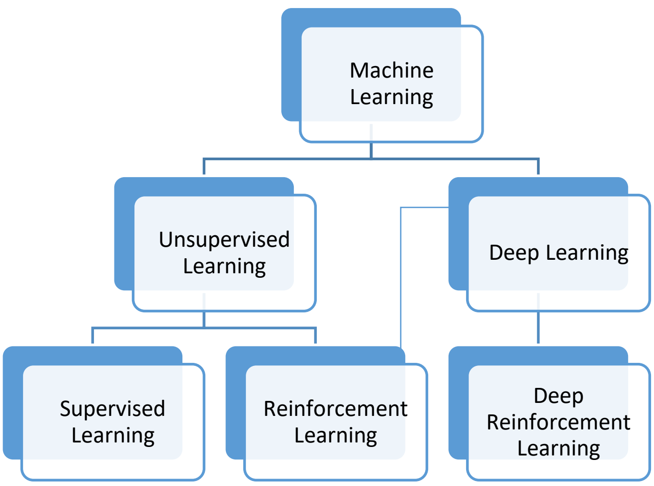


Figure 2-3 Methods of Machine Learning

2.4.1 Supervised Learning

In supervised learning, inputs are classified or labeled and the outputs are predicted then given to the system. Algorithms in supervised learning are trained using labeled data as input where the desired output is already known. The learning algorithm receives inputs and outputs corresponding to the correct inputs. It learns by comparing the algorithm's actual output with its correct outputs. A modification of the model is then implemented to correct the error. In supervised learning, patterns are used to predict the values of the label on additional unlabelled data by using methods like classification, regression, and prediction. This method of learning is commonly used in situations where data is used to predict future events. We want, for instance, to create a system that can automatically determine whether the images we supply contain a cat [55]. If first a cluster of various cat images is constructed, and then after one without cats is created, this is called supervised learning. Hence, training data is prepared. Then, the information from the training data is subsequently learned. Based on these, updated information is analysed, and then a decision is made based on the information analysed [51].

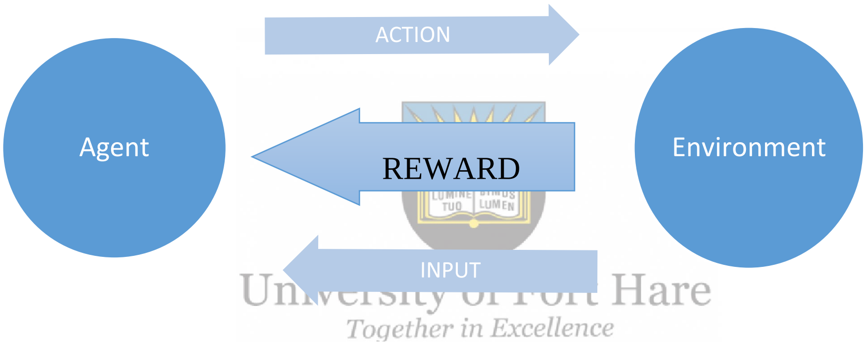
2.4.2 Unsupervised learning

University of Fort Hare
Together in Excellence

The unsupervised learning method is used when training data that has no labels. The system has no predicted outputs. An unsupervised learning algorithm must find out on its own what is being shown. The objective is to investigate the data and discover some structure within the data [56]. The unsupervised learning method processes the data input and then determines the output. This method does not establish a relationship between input and output like the supervised learning approach. As a result, it requires more datasets than the supervised learning approach. An unsupervised learning algorithm tries to find useful patterns for categorizing data. As unsupervised learning algorithms process data, natural clusters are revealed due to clustering algorithms used in this method. We can elaborate by saying that it is a hierarchical cluster used in unsupervised learning methods to groups customers according to their gender and age [51][55].

2.4.3 Reinforcement Learning

Reinforcement learning is a Machine learning-based method that gives a reward or penalty for each movement of the object that we want to train. Robotics, gaming, and navigation are common uses of reinforcement learning. Through trial and error, the algorithm determines which actions will produce the most rewards. Three primary components make up this type of learning method: the learner or the decision-maker (agent), everything the agent interacts with (environment), and what the agent can do (actions) [55]. The aim is to maximize the expected reward over a course of time, therefore the agent ought to choose actions that maximize the expected reward. The agent will be able to achieve the goal much more rapidly with a good policy. Thus, reinforcement learning implies learning the most efficient policy. For instance, we want our dog to bring an object back to us at home. Here, the dog is the agent, while the environment is the home. The dog will get a right or wrong response whenever it begins to move. As a result, the dog can understand or make sense of its movements. As the dog tries several times to get the object we want, it eventually gets it and begins to bring it to us. Thus, this procedure is called reinforcement learning [51]. Figure 2-4, shows the working principle of this learning.



University of Fort Hare
Together in Excellence

Figure 2-4 Reinforcement Learning Working Principle

2.4.4 Deep learning

Deep Learning is a Machine Learning based method that involves conditioning a machine to perform human tasks, such as recognizing speech, recognizing faces, enhancing images, identifying images, or making predictions. Rather than arranging data into predefined balances, in-depth learning frameworks define basic data criteria and train the machine to think independently through correlations across several layers of computing [57].

2.4.5 Deep Reinforcement Learning

Deep Reinforcement Learning is also a Machine learning-based method that combines deep and reinforcement learning. A highly active and advanced research field in Machine Learning, DRL has solved numerous problems that once seemed impossible including achieving superhuman performance in “complex games.” It is anticipated that it will solve more complex problems in areas such as robotics, resource management, and almost any field requiring decision-making capabilities in the future. Across numerous sectors, including robotics, finance, and healthcare, machine learning has provided great and various benefits. Besides smart homes, machine learning is been utilised in various sectors [51]. Figure 2-5 shows some areas of ML applications.

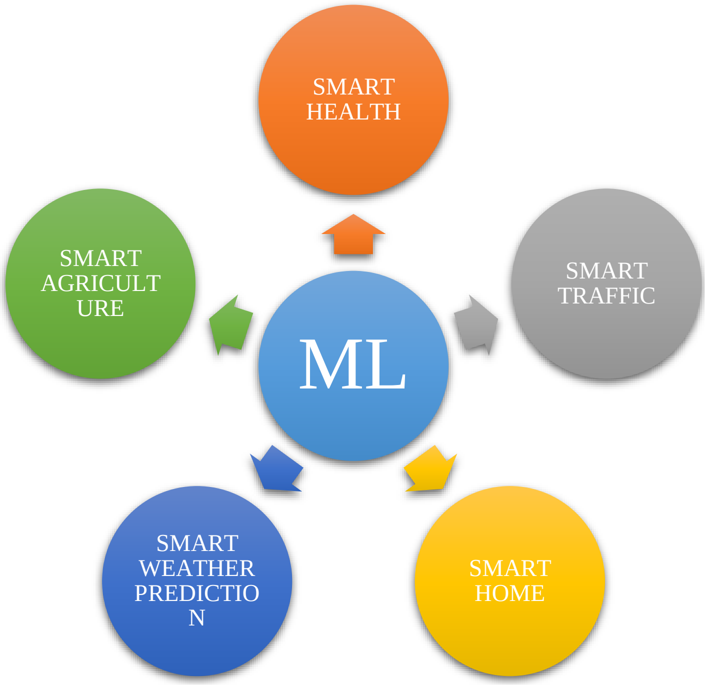


Figure 2-5 Machine Learning sector applications

Sensor data is the key component in machine learning for smart homes applications. Data gathered in real-time and historical data provides the basis for smart home decision-making. Let's consider an example where the tenant comes home at 6 pm every day, takes a shower, makes his coffee, then turns on his TV. By using smart home sensor data, the learning algorithm can learn the user’s daily routine and predict his next steps. As soon as the user opens the house door, the bathroom lights turn on, then after the coffee maker turns on also, after taking his coffee, the television turns on. As a result, the light in the house is controlled based on the user's routine, thereby providing energy management [51].

Human-machine interaction is quite high in smart home systems. With natural language processing and virtual assistants such as Google Assistant, Alexa, and Siri, it can control the devices in the house by voice commands such as turning on the lights and turning off the TV. Using the cameras in the house, the user can receive information and any unusual activities from his house based on the facial data collected. An optical scanner can be used to record fingerprint data allowing the user to unlock doors. Thus, Machine learning applications in smart homes include Face Recognition, Biometric Access Control, Energy Management, Natural Language Processing, Security as well as Activity Recognition [51].

2.5 Internet of Things (IoT)

MIT co-founder Kevin Ashton introduced the concept of the internet of things in 1999 while speaking at a presentation about the Auto-ID Center [27]. To attract P&G's (Protect and Gamble) attention to radio frequency identification (RFID) the managing directors, Kevin Ashton titled his presentation "Internet of Things" which was a way to slot in the new development of 1999 (the internet). In the same year a book, "When Things Start to Think", written by Neil Gershenfeld, a professor at MIT surfaced. Neil's book did not use the precise word used by Ashton, but it gave a rich and perfect perspective of, where the Internet of Things (IoT) was headed to [27].

The internet of things emerged from the merging of diverse technologies including wireless technology, micro-electromechanical systems (MEMS), micro-services, and from the internet. The convergence from these technologies has facilitated the communication between the operational technologies (OT) and information technologies (IT), giving ways to appliances that generate unstructured data to be analyzed for understanding and perfections [8].

University of Fort Hare
Together in Excellence

The knowledge of connecting devices together has been the scene since the 1970s, called "embedded internet" and "pervasive computing", although Ashton first talked about the internet of things in 1999.

In the 1980s, the University of Carnegie Mellon used one of the first internet appliances, a Coke machine. By the use of a web interface, developers were able to monitor the condition of the Coke machine and could deduce whether the machine had cold drinks or not [8].

The internet of things is a progression of machine-to-machine communications (M2M), the machines are connected via the network and do not need any human interaction to communicate. Internet of things then acts like an antenna in the network that connects smart devices that interconnect applications, systems, people, and many other applications that collect data and share it. M2M communication gives connectivity of devices that enable IoT.

Figure 2-6 IoT [25]

2.6 Wireless Communication Protocol

Smart home systems are using more wireless communication protocols due to the advantages they have over the wired communication. Wireless communication protocols are easy to use and have lower costs of installing devices and of setting up the network [9].

Mobility, Expandability, Cost, and Flexibility are some of the advantages wireless communication has over wire communication. Table 2.3 gives a brief description of the advantages of wireless communication protocols.

Mobility	Without losing the connection between devices, they can be moved around, since devices do not need a physical connection.
Expandability	New devices can be added easily to a network. Wireless networks are easy to scale.
Cost	Wireless networks are simple to set and have a lower cost of installing devices and setting up the network.
Flexibility	Building a wireless communication network in a new environment Can be as easy as linking a device directly to a power supply.

Table 2.1 Advantages of wireless communication protocol

2.6.1 Wireless protocols commonly used in smart homes

Wi-Fi, Bluetooth, and ZigBee are the most popular wireless technologies used in IoT devices in smart homes. These technologies can be categorized by data rate, range, and power consumption.

2.6.1.1 Wireless Fidelity (Wi-Fi)

The Internet protocol for wireless communication Wi-Fi also known as Wireless Fidelity, is a communication protocol established on the IEEE 801.11 standard developed by the Institute of Electrical and Electronic Engineers (IEEE) regulation. No license is required in using Wi-Fi; therefore, it has become the most popular technology in use in the present day. Wi-Fi can cover an area of about 45 m indoors, its boundaries can be increased with a Wi-Fi extender and redundant Wi-Fi access points, and this makes the Wireless Local Area Network (WLANs) fit for this technology. The technology can function on the frequency of 2.4 to 5.8 GHz scale and can use the WPA2 encryption; Wi-Fi Protected Access 2 offers stronger data protection over the network and provide a network access control [9]. The technology is intended for connecting devices in a WLAN under the IEEE 802.11 regulation. IEEE 802.11b/g/n works on a 2 GHz band, whereas IEEE 802.11a/n/ac uses 5GHz.

Billions of devices with incorporated Wi-Fi technology are in use presently. The technology is mostly used to control lights, monitor power consumption, door and garage locks, surveillance, sensor, and so many more application in the IoT domain. There is no use in buying costly gateways to connect IoT devices, because of its native compatibility with the IP. The electronics market is boosting the technology in IoT because of its significant cost savings.

University of Fort Hare
Together in Excellence

Wi-Fi technology can be used in a home automation system as a network infrastructure to allow connectivity between a server and *hardware interface modules*. The wireless fidelity can improve security in a system, and can also increase mobility and scalability in a system, which permits a user to add new modules which are out of the range. As discussed previously, Wi-Fi technology permits users to monitor and control appliances in smart home systems in a wider range and anywhere using a mobile phone [33].

2.6.1.2 Bluetooth

Bluetooth is a wireless technology that uses short-range communications technology, which uses radio waves instead of wires to connect devices. Bluetooth is a popular wireless technology founded on the IEEE 802.15.1 regulation and most used in Personal Area Networks (PANs). It can run on a frequency of 2.402–2.480 GHz ranges or can work on 2400–3483.5 MHz, which supports numerous channels, with a frequency of 1 MHz for each channel. The technology can use frequency hopping spread spectrum (FHSS) to avoid busy channels to use none busy channels to communicate with other interconnect devices [10]. In the quest of improving ranges and increase in data rate, the Bluetooth 5 was introduced and brought various developments for the Bluetooth Low Energy (BLE), which is used for lower power devices working in mobile phones battery. Several enhancements have been made for the Bluetooth Low Energy version, including improved range, improved channel selection, and more data transmission speed, in order to support emerging IoT devices. [9].

Bluetooth technology is widely used in home automation systems for direct and short-range control and monitoring appliances in smart home applications. A smart home system Bluetooth-based can control appliances of home via relays that are connected to the I/O of an Arduino Bluetooth board [34][36]. Bluetooth technology provides security, less cost, and stable connectivity in a short-range. A Bluetooth mesh, which is a development from Bluetooth technology, plays a crucial role in today's smart home systems; it provides reliability, high performance, and flexibility in the network [35].

2.6.1.3 ZigBee

Just as mentioned with the previous technologies, ZigBee wireless technology is also an IEEE 802.15.4 standard based. The ZigBee wireless technology does not cost much, it is reliable, and has a low-rate communication technology that is intended for devices that have a limited power supply. The technology is widely used for building devices with lower power. ZigBee is free and open-source; this makes it a prime choice by retailers to manufacture low-powered devices. It can run on a frequency of 868 MHz – 2.4 GHz and have a data rate that is 20 - 250 kbps and can cover an area up to 100 m [12].

University of Fort Hare
Together in Excellence

ZigBee uses multi-hop transmission to increase the range of activities in the network. Multi-hop transmission is a wireless network that uses multiple wireless hops to transmit information from one destination to another. Multi-hop networking has two different applications, with a mutual attribute, namely Mobile ad hoc networks (MANETS) which comprise of a group of linked together mobile nodes, and transfer data without any wireless setup. Multi-hop cellular networks is a cellular system that uses a single hops mobile units and the station [13]. Using the multi-hop transmission can surely increase the range and this can at times lead to an effect called the "popcorn effect", the message is sent from one end to another before its final destination that leads to a delay before it reaches its destination. It has a default maximum number of 5 hops, this implies that if the message that was propagate does not reach its end point after 5 hops, the message will be cast-off, and will never reach the intended receiver [9].

	Wi-Fi	Bluetooth	ZigBee
Standardization	IEEE 802.11	IEEE 802.15.1	IEEE 802.15.4
Frequency	2.4 to 5.8 GHz	2.402 to 2.48 GHz	868/915 MHz, 2.4 GHz
Data rate	450 Mbps	0.7 to 2.1 Mbps	20/40 kbps, 250 kbps
Range	10 to100 m	15 to 20 m	10 to 100 m
Network size	Thousands (mesh)	8	65,536
Network Topology	Tree, Star, mesh, P2P	Star	Star, cluster tree, mesh
Encryption	WPA2	AES-128	AES-128

Table 2.2 Most commonly used wireless protocols

Table 2.4 gives a brief description of the technologies in frequency, range, data rate, network size, network topology, and their standardization.

Just as the previous technologies, ZigBee technology also plays a great role in smart home networks. The technology can provide security [37][38], smart surveillance [39][40], energy management [41][42], and assistive home applications in smart home networks [43][44]. Home automation systems based on ZigBee have been suggested in many applications. Home security systems based on ZigBee technology are commonly used today [37]. The home system can monitor window, door, smoke, water flooding, and gas leak in a smart home from a different location remotely [45].

University of Fort Hare
Together in Excellence

2.7 Related Work

The idea of having smart, connected, autonomous, houses that will anticipate needs of residents, as always been a vision even before the Internet of Things concept emerged, where the subsystems act independently and always aware of one another.

The process of creating a ubiquitous automated house and improving human life has led to a variety of approaches to develop smart houses, ranging from traditional programming to machine learning-based solutions, which aim to improve comfort, energy efficiency, and even human activity recognition.

A review of several publications was conducted in order to better understand what has already been done regarding smart homes that was build using AI and Machine Learning methods. Mehmet Mücahit [51] have a developed an automatic system capable of being self-sufficient and responding to requests. The research studied the possibilities of applications of Artificial Intelligence for domestic usage, particularly in home management systems that can reduce consumption, wastes and optimizes the usage of resources to positively impact in a small and large scale. To achieve this goal, the study highlighted possible uses of machine learning, deep learning, and reinforcement learning. The machine was trained using Machine learning to make decisions and optimise decision-making operations. Meanwhile, deep learning improved upon the ML concept by introducing additional neural networks that enabled a range of possible operations from object detection to real-time motion analysis problems. Finally, the reinforcement learning tracked and optimized the resource management using a learning computer that worked on the concept of success and failure. The system was said to be useful in areas such as energy management, food & agriculture, water consumption & generation, waste management, health-care, customization, entertainment and security. The Home Management System (HMS) is said to be more advanced in the future. The HMS was classified into five different levels: Level 0 with a limited number of devices, Level 1 where a connection with a large number of devices and manual management is provided by systems such as mobile applications, Level 2, the HMS started to perform basic manual automation, Level 3, the smart system is powered by AI, and Level 4 the HMS can manage all daily tasks. [58] proposed a system model that can integrate gas leakage and fire systems detection within a smart home in order to increase safety by making use of low cost and less energy consumption devices through Machine -2-Machine (M2M) standard communication protocols. Then, using machine learning approach, data mining method was involved, with the information received from the sensors the system was able to detect abnormal changes for a quick prediction of the risk incidences. From their data set, supervised machine learning process was applied to observe events that did not conform to the expected pattern, and also to predict the level of risks. Yanfei Peng et al [59] presented a smart home control system based on the strength of human body point cloud data attitude recognition technology. Where in, the human body point cloud image is obtained by Kinect, and the point cloud image is extracted, and the human body attitude is recognized by Convolutional neural network (CNN) algorithm. The received data was processed using Arduino microprocessor to accomplished the intelligent part of residential electrical appliances in the process. From the findings the system was able to recognition human attitude and effective control of household appliances. Finally, Ricardo Silva Peres [60] proposed an architecture that focused on the use of an online learning to develop a smart home capable to control diverse devices that are connected together following the user's habits and preferences. The proposed solution was integrated with a voice control possibility, that could control devices using a mobile application or again using a web interface. The study proved that the techniques used to develop the voice activated smart home controller using machine learning would be easily integrated to any other intelligent home. Erol, Y., et. al. in [61] described a

University of Fort Hare
Together in Excellence

remote-control system based on a microcontroller PIC16F84A. This system was designed to control electricity using mobile phones. The idea of the system was that when the user enters the pin numbers, the microcontroller-based remote-control circuit, checks the pin numbers that have been entered. If the pin numbers are correct, the controller will control the devices via a telephone line or mobile phone. The system's benefit is that unauthorized users cannot access it. It is, however, a very difficult system to use, as it requires the user to memorize pin numbers [61].

2.8 SUMMARY

This chapter answered the first two questions stated in chapter one. The search, collection and selection for relevant articles was also explained. The chapter gave an overview of smart homes and their benefits in modern days. The chapter gave an overview of different application techniques that can be used in the development of smart homes. An overview of related study using Machine Learning methods was carried out. This chapter also gave a brief history on internet of things, from the first time it was mentioned to it first application in a day-to-day life. Different wireless technologies mostly used in smart home systems and their use in smart home networks such as ZigBee, Bluetooth, and Wi-Fi, were discussed and categorized by data rate, range, frequency, network size, network topology, and encryption.

University of Fort Hare
Together in Excellence

CHAPTER 3: METHODOLOGY

3.1 Introduction

This chapter presents and discusses the procedures used for this study. The study used three standard methodologies. Firstly, for reviewing literature to understand the underlying problem and to learn what other researchers have done, the study used systematic literature review methodology. This approach allowed a critical analysis of the existing literature. Systematic literature review can take two forms: meta-synthesis and meta-analysis. Meta-synthesis allows researchers to integrate, evaluate and interpret the findings of other studies. It is inductive in nature. On the other hand, meta-analysis consists of taking findings from other studies and analysing those using statistical methods. For this study the approach was deductive hence we applied meta-synthesis type of systematic literature review. In order to ensure that the objectives of the project were fulfilled, the project used the waterfall model approach together with the system development process. Software development is governed by the waterfall model, which explains the process in a linear progressive way. For system evaluation, the study applied simulation methodology. This allowed a closer analysis of the system's behaviour under different conditions. In the next sections, we give more details of the study's approach

University of Fort Hare
Together in Excellence

3.2 Approach

Table 3.1 shows the methodology used to accomplish the aim of this research.

	Objectives	Research Question	Approached Methodology
1	To review the techniques or technologies for the development of smart homes' mobile base control systems.	What are techniques are used for the development of smart home systems? What are communication technologies are used with smart home systems?	Systematic Literature review (meta-synthesis)
2		How to design and implement a smart home mobile base control system using Arduino Uno microcontroller?	

3	To design and implement a smart home mobile-based control system.	Which methods could be used to link up a wireless network communication between an android based smartphone and a smart home system with a microcontroller such as the Arduino Uno?	Design and implementation
	To evaluate the reliability and efficiency of the developed mobile-based smart home control system		Simulation of the system and analysis of the results

Table 3.3 Steps used in research methodology

3.3 Design and implementation

- Step one: all the software (Arduino IDE, Proteus design suite, MIT App inventor and Firebase) and libraries (ESP8266, ESP8266 ESP-12F, Arduino boards libraries for proteus, and other libraries) needed for the project were gathered.
- Second step: The installation of Arduino IDE and Proteus design suite on the computer was successfully done. The MIT App inventor and Firebase are online free software that only required creating an account to be able to use them. Authentication key from Firebase was used to link MIT App inventor and Arduino IDE for access purposes.
- Third step: the system design on the Proteus design suite was successfully accomplished, and the following steps were taken in implementing the design:

University of Fort Hare
Together in Excellence

3.3.1 Using the virtual terminal:

Arduino board was connected to the Virtual terminal by linking the board RX pin to the RXD pin on the virtual terminal, then the TX on the board to the TXD of the virtual pin as presented in Table 3.2.

	Arduino Board	Virtual Terminal
1	RX	RXD

2	TX	TXD

Table 3.4 Arduino board vs Virtual terminal through their respective pins.

Table 3.3 presents the connection from the board to the diodes, resistors, relays and lights. As presented in the table, Pin13 on Arduino board is connected to diode one (D1) which is linked to relay one (RL1), then connected to Light one (L1). In this manner all the connections between the components were done. A complete visual design is presented in Figure 5-1.

	Arduino Board	Diode Nb	Resistor Nb	Relay Nb	Light Nb
1	Pin13	D1	R1	RL1	L1
2	Pin12	D2	R2	RL2	L2
3	Pin11	D3	R3	RL3	L3
4	Pin10	D4	R4	RL4	L4

University of Fort Hare
Together in Excellence

Table 3.5 Arduino and Lights.

- The fourth step was to program an algorithm in Arduino IDE, then run and debug the program. After running the program, it was sent to the Arduino board for communications between appliances and the virtual terminal.
- The firth step was to connect the microcontroller with the Wi-Fi module and appliances in the system.

3.3.2 Using the mobile-based control application

	Arduino Board (Pin Name)	NodeMCU (Pin Name)	ESP86-12F (Pin Name)
1		3V	VCC
2		GND	GND

3	TX 1	TXD	TXD
4	RX 0	RXD	RXD
5	A4	D1	
6	A5	D2	
7	RST	RST	RST

Table 3.6 Connectivity between Arduino boar, NodeMCU, and ESP8266-12F.

	Arduino Board	Diode Nb	Resistor Nb	Relay Nb	Light Nb
1	Pin13	D1	R1	RL1	L1
2	Pin12	D2	R2	RL2	L2
3	Pin11	D3	R3	RL3	L3
4	Pin10	D4	R4	RL4	L4

University of Fort Hare
Together in Excellence

Table 3.7 Connectivity between Arduino and Lights.

- Step six: the database was set and retrieved the authentication key which is used for allowing access to the database. Firebase was used as a database. Firebase is a free package of google, before creating a database on Firebase one needs to create a google account.
- Step seven was to design the android mobile application using the free online App creator MIT App inventor. The MIT App inventor program is straightforward and easy to use. After a complete design, the app was connected to the database using the same authentication key used in writing the Arduino code. Then installed on Android mobile for control purposes.

3.4 Simulation

The simulation process and design phase of the mobile-based control system were done using a simulation tool, the Proteus design suite. ESP8266 Add-on had to be installed in Arduino IDE as first step. The following step was followed:

- Open the Arduino IDE and click **File** > **Preferences**

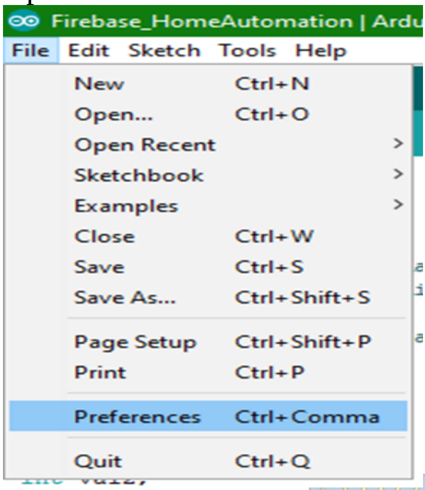


Figure 3-1 Arduino File Preferences

- Figure 3-2 below shows how to enter the full path for the package **http:// arduino.esp8266.com/stable /package_esp8266com_index.json**. Then, click the "OK" button:

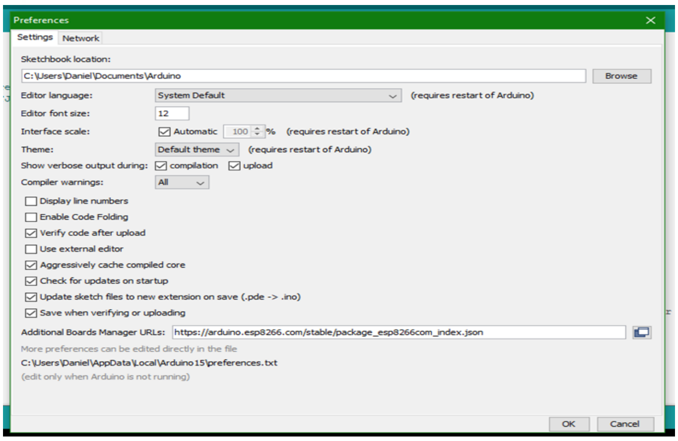


Figure 3-2 Arduino ESP8266 Add-on.

- Step 3: To open the Boards Manager. Navigate to **Tools** > **Board** > **Boards Manager**

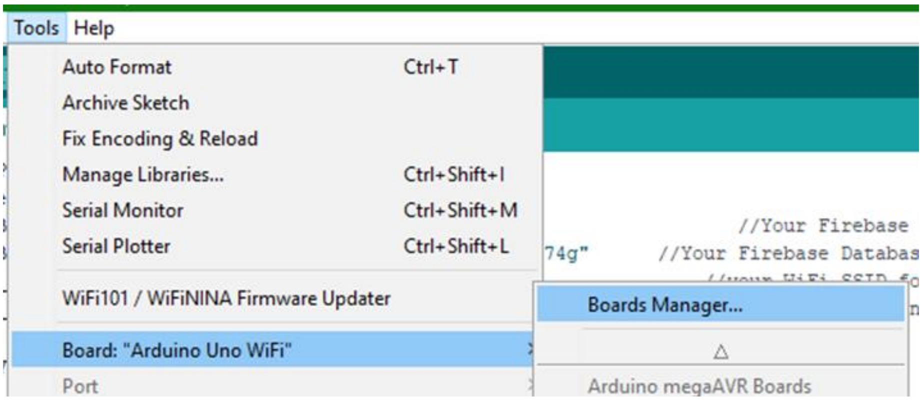


Figure 3-3 Arduino Board Manager

- Step 4: Click on "ESP8266 by ESP8266 Community", then the "ESP8266 by ESP8266 Community" will be installed.

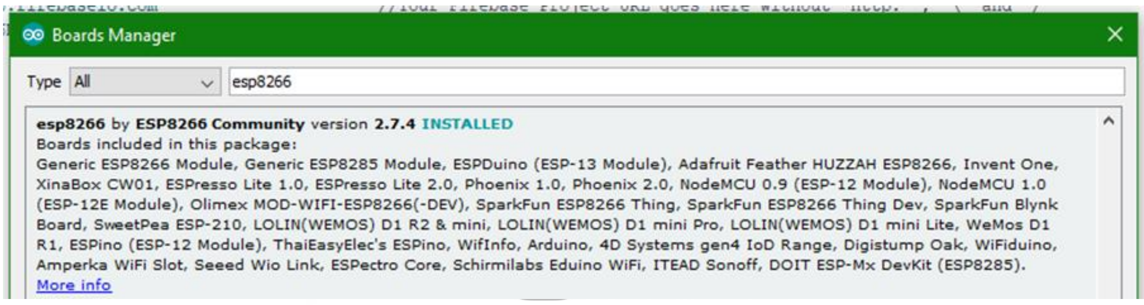


Figure 3-4 esp8266 by ESP8266 Community Installation.

After the installation of EP8266, the next step was to debug and run the program by clicking the verify button or by going to sketch then verify. The location of the file “**hex**” was generated in Arduino. Figure 3-5 shows the address of the location generated file circled in green.

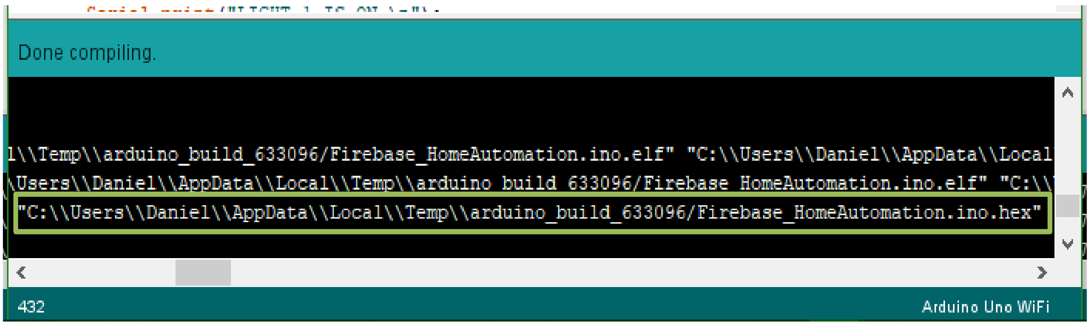


Figure 3-5 Copy hex location address.

After the file location was generated, the next step was to copy the location address of the file, open Proteus design suite, then go to the ISIS design, double click on Arduino image, then past the path in the field shown in Figure 3-6 circled in green, then click “**OK**”.

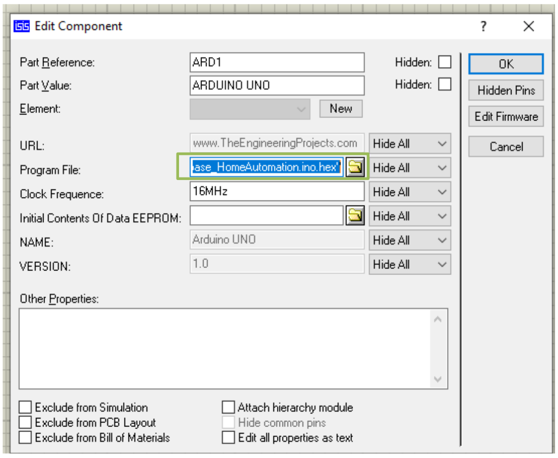


Figure 3-6 Paste the hex file in the Arduino board at Proteus

After successfully implemented the above steps, the final step was to run the designed system on ISIS design and place commands from the Android mobile application control system, to control appliances and test the state of switching ON and OFF appliances. The simulation of the system went on from June 2020 to October 2020, each time we had to try and find the missing library when facing this dilemma. Libraries used are presented in Appendix B.

University of Fort Hare
Together in Excellence

3.5 Analysis of results

3.5.1 Time taken to turn ON/OFF the appliances

Ten trials were conducted to help in determining the performance of the implemented system. For performance, the study determined the average time it took to turn ON/OFF the appliances. To do this, two scenarios were used, command from the same location and command from a different location. To compute the average time, the study used the following mathematical equation:

Let, $\boldsymbol{Av_t} = \frac{\boldsymbol{T_t}}{\boldsymbol{N}}$ ------------------------------ **(1)** With $\boldsymbol{Av_t}$ $the\ average\ time\ in\ second\ (sec).$

$-\ \boldsymbol{T_t}\ the\ \boldsymbol{sum}\ or\ \boldsymbol{total}\ times\ taken\ for\ each\ trial\ in\ second\ (sec).$

$-\ \boldsymbol{N}\ number\ of\ trials\ conducted.$

Were, $\boldsymbol{T_t} = t_1 + t_2 + t_3 + \cdots + t_n$ ---------------- **(2)**

With: $- \ \boldsymbol{t_n}\ time\ taken\ for\ each\ trial\ in\ second\ (sec)$.

3.5.2 Reliability

The other performance measure used was to test the reliability of the system. To do that, the study used mean time to failure (MTTF). The mean tine failure also known as maintenance metric or lifespan of an asset, calculates the number of operational hours of a non-repairable asset before it fails. The mean time to failure was used because the system used non-repairable assets. The following equation was used:

Let, MTTF $= \frac{T_h}{T_a}$

With: $- \ \boldsymbol{MTTF}$ mean time to failure $(hours)$.

$- \boldsymbol{T_h}$ Total hours of operation $(hours)$.

$- \boldsymbol{T_a}\ Total\ assets\ in\ use$.

3.6 Summary

This chapter presented the steps that were followed to achieve the objectives of this research. The chapter also presented three standard methodologies the study used. For reviewing the literature, the study used systematic literature review methodology to understand and to learn what other researchers have done. For implementation, the study used waterfall model as a methodology. For system evaluation, the study applied simulation methodology. Key issues that were also discussed include the design, implementation and simulation of the system. This chapter explained and demonstrated the steps taken to design, implement and simulate the system primarily by using a virtual terminal and secondly using the mobile-based control application. This chapter also explained the process of connecting Arduino board, virtual terminal, Wi-Fi module and appliances. Moreover, analysis of the results was discussed. In particular, the study tested the reliability of the system and average time it took to turn ON/OFF the appliances, which are performance measures that were also discussed.

University of Fort Hare
Together in Excellence

CHAPTER 4: PROPOSED SYSTEM AND COMPONENTS USED

4.1 Introduction

This chapter answers the last two research questions; question three and question four as stated in chapter one. To address the study questions, a detailed description of each component and software used and required in this study to successfully design and implement the system was given. A summary of the proposed system is also presented in the chapter. The remainder of the chapter can be summarized as follows: section 4.2 gives a summary of the proposed system. Section 4.3 presents a detailed description of Arduino Uno board, its specifications, pin function descriptions and how the board works. In section 4.4, a detailed description of the Wi-Fi module is given. The section also gives the specifications of the component, pin function descriptions and how the board and Wi-Fi module are integrated. Section 4.5 presents a brief discussion of relay board, its pinout descriptions and how it is connected with the Arduino board. Section 4.6 gives a brief description of the online open-source design software, MIT App inventor, used to design the android mobile application. Section 4.7 presents a short description of Firebase online free storage application. Section 4.8 describes Proteus design suite, the software used for schematic design system and simulation of the system. Section 4.9 presents the Arduino IDE used for the backend programming which also allow the microcontroller to comprehend commands. Section 4.10 presents the flow chart algorithm. Section 4.11 concludes the chapter.

University of Fort Hare
Together in Excellence

4.2 Proposed System Overview

The home automation system is made up of a microcontroller Arduino Uno board, Relays, online data storage (Firebase) which stores data from all commands between the android application command and appliances for later use. The Wi-Fi module, was connected to the principal device; the Arduino board through the Wi-Fi module obtains a command from the Android mobile application to control the appliances in a home automation system. As the frontend, a mobile Android-based application was used as a software communication that communicated with the board. The android application served as a user interface.

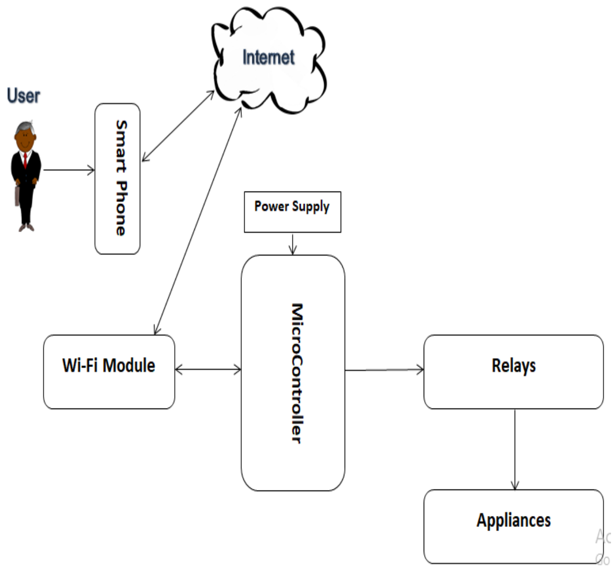


Figure 4-1 System Architecture

The appliances in the system are controlled or switched ON/OFF with relay switches. A Wi-Fi module was used to allow connectivity with the Arduino Uno board, which is the microcontroller. The Wi-Fi module procures internet connectivity, and permits access to the internet and control the system using the mobile based android application. The android interface allows the user to view the state of appliances, which can be either active or not active, and controls them as required.

4.3 Description of components

4.3.1 Arduino Uno Board

Arduino Uno is a mini-computer or micro-controller Board based on the ATmega328P allowing the interaction of objects [14]. The device is capable of processing data just like a computer. The board uses the Arduino IDE Software for programming which allows the microcontroller to interpret the command of a specific appliance in a particular home with the use of a smartphone. 14 digital input/output pins are attached to the board of which six of them can be utilised as Pulse Width Modulation (PWM) outputs, input pins for six analog signals, featuring a 16 MHz ceramic resonator (CSTCE16MOV53-RO), a USB port, a power jack, an in-circuit serial programming (ICSP) header, and an on-button reset [14].

Figure 4-2 Arduino Uno Board

IN LUMINE TUO VIDEBIMUS LUMEN

Table 4.1 gives a specification of Arduino Uno

Microcontroller	ATmega328
Operational Voltage	5 Voltage
Voltage at which input is recommended	7V to 12 Voltage
Limits on input voltages	6V to 20 Voltage
Pins for analog input	6
Pins for digital input and output	Fourteen pins, including six pins provided with PWM outputs.
Input and output Pins DC currents	A 40-mA source
The DC current flowing at pin 3.3V	With 50 milliamps
Memory Flash	A 32KB bootloader uses 0.5KB of the available memory
SRAM	A 2 KB
EEPROM	1 KB
The clock speed	16 megahertz
In-built LED	13
PMW Digital I/O Pins	6

Table 4.8 Arduino Uno specifications

4.3.2 How does Arduino Board work?

Arduino programs use digitalWrite(), digitalRead(), also pinMode() methods to operate on the 14 pins as input and output signals on the board. The pins function at a 5V each and can receive and provide a maximum current of 50mA, with a 20-50KOhms internal pull-up resistor [15]. Table 4.2 shows some pins having specific functionalities among the 14 pins.

Pin	Description
(Rx) pins 0 on the serial interface	The ATmega328P USB to TTL serial chip is connected according to the Rx pin, which is used to receive TTL serial data.
Serial Pins 1 (Tx)	Atmega328P USB to TTL serial chip connects to the Tx pin to transmit data in TTL serial format.
Pins 2 and 3 of the external interrupt system	An interrupt will be triggered on low values from these pins.
Three, five, six, nine, and eleven of the PWM pins	Using the analogWrite() function, you get an 8-bit PWM output.
SS pin 10 (SS), MOSI pin 11 (MOSI), and SCK pin 13 (SCK) of the SPI bus	SPI communication takes place over these pins.
Pin 13 of the built-in LED	A visual signal is given by the LED installed on pin 13 when HIGH, the LED illuminates, and when LOW, the LED is in the off state.
Pins 4 (SDA) and 5 (SCA) from the analog board	TWI communication is achieved using a library of wires and pins
AREF	For the Analog inputs, analogReference() provides a reference voltage, using the pin AREF
Reset Pin	This pin resets the microcontroller by making LOW.

Table 4.9 Pin description

From the 14 digital pins, 6 Input pins for analog signals provide a 10 bits resolution of each and operate with a limit of 0V to 5V which can be increased using the AREF pin by using the function analogReference(). Arduino board features a Wi-fi port, a Wi-fi socket, module interface and an ATMega328. Hence, the use of Arduino board in the study is to add connectivity in the network using wireless ESP8266 wi-fi shield control.

4.4 Wi-Fi Module (ESP8266)

The WIFI Module ESP8266 is based on CT (cadence Tensilica L106) of 32bit MCU that is manufactured by Espressif Systems. ESP8266 belongs to the ESCP (Espressif Systems Smart Connectivity Platform) and based on SoC (System on Chip), the ESP8266 SoC function on the TCP/IP protocol that permits microcontrollers to be connected to the Wi-Fi network [16].

ESP8266 can be programmed directly on a microcontroller chip, with the help of SDKs (Software Development Kits), with no need for an external microcontroller. Based on ESP8266 SoC, manufacturers such as Ai-Thinker began to produce customized boards. The first manufactured board by Ai-Thinker was the ESP-01. Upon the success of the ESP-01 Module, many more modules were brought to light, such as ESP-02, ESP-12, and many more. The boards are based on the ESP8266 SoC and only differ by the numbers of general-purpose input/output (GPIO) Pins [16].

4.4.1 ESP8266 ESP-12F

As mentioned in section 4.3, the ESP-12F Wi-Fi module is a product of Ai-Thinker Technology. The IEEE802.11b/g/n standard is supported by this device. The stack consists of all TCP and IP protocols. By using the Wi-Fi module, networking capabilities can be given to devices that had no networking capabilities [17].

University of Fort Hare
Together in Excellence

The Wi-Fi Module provides the board with connectivity to the Internet, which will facilitate the communication between the android mobile application commands and microcontroller responses. ESP-12F module has 16 pins, operates on the voltage of 3.0-3.6V, operating on 80mA current, Wi-Fi 2.4 GHz, and supports WPA/WPA2, and many more which are discussed in table 4.3 [18].

Figure 4-3 ESP-12F Wi-Fi Module

Table 4.3 gives a clear specification of the ESP-12F Wi-Fi module

Model	ESP-12F
Package	SMD22
Certification	FCC, CE, IC, REACH, RoHS
Serial Peripheral Interface Flash	Default 32Mbit
The interface	ADC/GPIO/UART/PWM
Input/Output Port	9
Rate of UART Baud	Supported bandwidth of 300~4608000 bps, default bandwidth is 115200 bps
The frequency	The 2412~2484 MHz
The antenna	Antenna For The PBC
Transmission of power	16±2 dBm for 802.11b; 14±2 dBm for 802.11g; and 13±2 dBm for 802.11n
R Sensitivity	-90dBm for 1Mbps and 11Mbps CCK; -85dBm for 6Mbps CCK; -88dBm for 54Mbps; -67dBm for HT20, MCS7
Power	The modem sleep current is ~20Ma; the light sleep current is ~2Ma Deep Sleep: ~0.02mA; 500mA
Security	The WEP/WPA2-PSK/WPA-PSK
Power Supply	The voltage is 3.3 V~3.0 V, and the current is over 500 mA

Table 4.10 ESP-12F Specifications

University of Fort Hare
Together in Excellence

4.4.2 Pin Definition

As mentioned in section 4.3.1 the Wi-Fi module ESP-12F has 16 pins having diverse functionalities. Figure 4-5 gives a pin description of the technology and detailed in Table 4-5

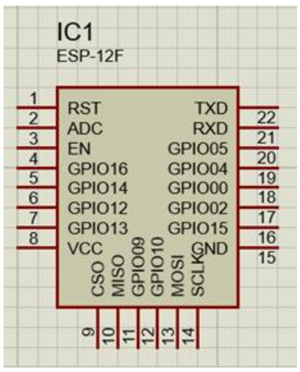


Figure 4-5 ESP-12F pin description

Figure 4-4 ESP-12F pin schematic representation

No	Pin Name	Description
1	TXD0	UART0_TXD; GPIO1
2	RXD0	UART0_RXD; GPIO3
3	GPIO5	GPIO5; IR_R
4	GPIO4	GPIO4
5	GPIO0	GPIO0; HSPI_MISO; I2SI_DATA
6	GPIO2	GPIO2; UART1_TXD
7	GPIO15	GPIO15; MTDO; HSPICS; UARTO_RTS
8	GND	GND
9	RST	Activate the reset pin when low
10	ADC	AD conversion, Voltage input range of 0~1 V, Value range of 0~1024
11	EN	This pin is turned on when the chip is enabled
12	GPIO16	To wake up from deep sleep, connect the RST pin
13	GPIO14	The GPIO14 and the HSPI_CLK pins
14	GPIO12	Inputs: GPIO12 and HSPI_MISO
15	GPIO13	Input devices: GPIO13, HSPI-MOSI, and UARTO-CTS
16	VCC	Power supply pins on the module, voltage 3.0V ~ 3.6V

Table 4.11 ESP-12F pin function description

4.4.3 Arduino Uno and Wi-Fi Module Integration

University of Fort Hare
Together in Excellence

The Wi-Fi modules must be connected to Arduino Uno to control the board.

- The Wi-Fi module ESP-12F is connected to the GND pin on Arduino Uno Board using 3.3V pin.
- ESP-12F Wi-Fi module is connected to Arduino Uno GND pin through VCC pin.
- Using Arduino Uno, the TX pin on the board is linked to the TXD on the Wi-Fi module.
- In addition, the Arduino Uno's RX pin is connected to the ESP-12F's RXD.

Table 4.5 shows the Arduino Uno Board's connection to the ESP-12F Wi-Fi module.

Arduino Uno Board	Wi-Fi Module
3.3V	GND
GND	VCC
TX 1	TXD
RX 0	RXD

Table 4.12 Arduino Uno and Wi-Fi module pin connections

4.5 Relay Module

Electrical relays use an electromagnet to open or close another circuit when they are activated by a low current at one end of a circuit. Connected appliances get turned on and off by the microcontroller via relay ports. The relay module is a device that is used to remotely switch ON/OFF devices over a network or the Internet. In our system, we used the four relay modules, which enabled the system to power on or off appliances remotely over the network, with commands from the Android mobile-based application.

Figure 4-7 Relay module

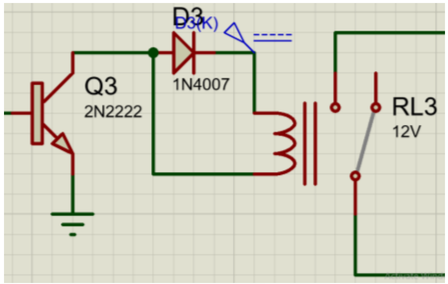


Figure 4-6 Relay module (switch) schematic representation

4.5.1 Relay Module Pinout Description

Table 4.6 shows the Relay module pinout.

University of Fort Hare
Together in Excellence

Pin Name	Description
NC	Normally closed terminal, close connection
COM	A common terminal, a pin that is usually connected to the ground unless using for HIGH Voltage.
NO	Normally open terminal, open connection
GND	The ground terminal linked to the ground pin to Arduino Board
VCC	Connects the 5V pin on Arduino, provide an input signal
SIG	the signal carries the triggered signal from Arduino to activate the relay module
IN1	An Arduino Uno board connected to a pin signal that controls relay1.
IN2	An Arduino Uno board connected to a pin signal that controls Relay2.
IN3	An Arduino Uno board is connected to a pin signal, which controls Relay3.
IN4	An Arduino Uno board connected to a pin signal that controls Relay4.

Table 4.13 Relay module pinout descriptions

Arduino Uno	Relay Module
Signal Pin 13	Pin IN1(Input 1), control Relay 1
The pin number 12	Pin IN2(Input 2), control Relay 2
The pin number 11	Pin IN3(Input 3), control Relay 3
The pin number 10	Pin IN4(Input 4), control Relay 4
5 Volts	Pin VCC
GND pin	Pin GND

Table 4.14 Relay module and Arduino Uno pin connection

Two types of contacts are found inside the relay module namely; NO normally open and NC normally closed with a common COM port that is supplied with current in both NO or NC configuration.

- When the normally open terminal receives a high signal, the switch closes the circuit and permits the flowing of current from the terminal normally open to the common terminal.

When the terminal normally closed receives a high signal or low signal, it releases the switch and stops the flow of current.

University of Fort Hare
Together in Excellence

4.6 MIT App Inventor

The MIT App Inventor is an online application that allows users to design and develop Android applications. It is used to design the user interface (UI) for applications that run on Smart Phones.

Figure 4-8 MIT App Inventor

4.7 Cloud Storage (Firebase)

Firebase is a Baas, a backend Service. It affords developers with a large portion of tools and services that help developers to build, improve, and grow apps. Firebase is a cloud storage program with a NoSQL database that stores data in JSON-format. Among the many different services it provides are analytics, authentication, configuration, databases, push messaging, file storage, and so many other services [47]. The services are stored in the cloud. In our project, we used Firebase to store data for later use.

Figure 4-9 Firebase

4.8 Proteus Design Suite

Proteus is a software tool developed by Labcenter Electronics for designing electrical and electronic circuits. It simulates and designs electrical and electronic circuits [45][46]. It is a software design suite that comprises schematic, simulation, and PBC designing. Using this tool, schematics can be drawn and circuits can be simulated in real-time. We used Proteus in this project to simulate the home automation system to control appliances in our home automation system.

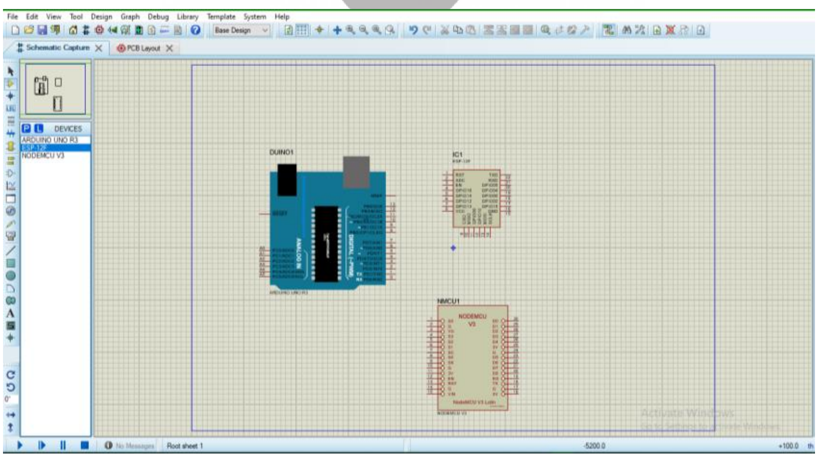


Figure 4-10 Proteus Design Suite

4.9 Arduino IDE

As mentioned in section 4.2.1. We used the Arduino IDE Software for backend programming, which allows the microcontroller to interpret the command of a specific appliance in a particular home with the use of a mobile application installed on a smartphone.

Figure 4-11 Arduino IDE Software

4.10 Flow Chart

Algorithm [48]

1. With the Android application on the smartphone, you can send signals, to the Wi-Fi module, which connects you to the internet. Each appliance's GUI buttons can be found in the Android application.

2. The mobile application sends signals to the Wi-Fi module, which then passes them on to the microcontroller board to be processed.

3. A microcontroller board was used to control all the appliances in the system. Connected to the microcontroller board are the relay board and Wi-Fi module. Each command is processed by the micro-controller board and control the relay board for switching on/off the appliances

4. Relays board were used as electrical switches, performing on/off operations. The power supply is provided through the relay board to the appliances.

5. Additionally, with the mobile app for android, the user can command the Wi-Fi module attached to the microcontroller, which in turn commands all appliances in the smart home.

University of Fort Hare
Together in Excellence

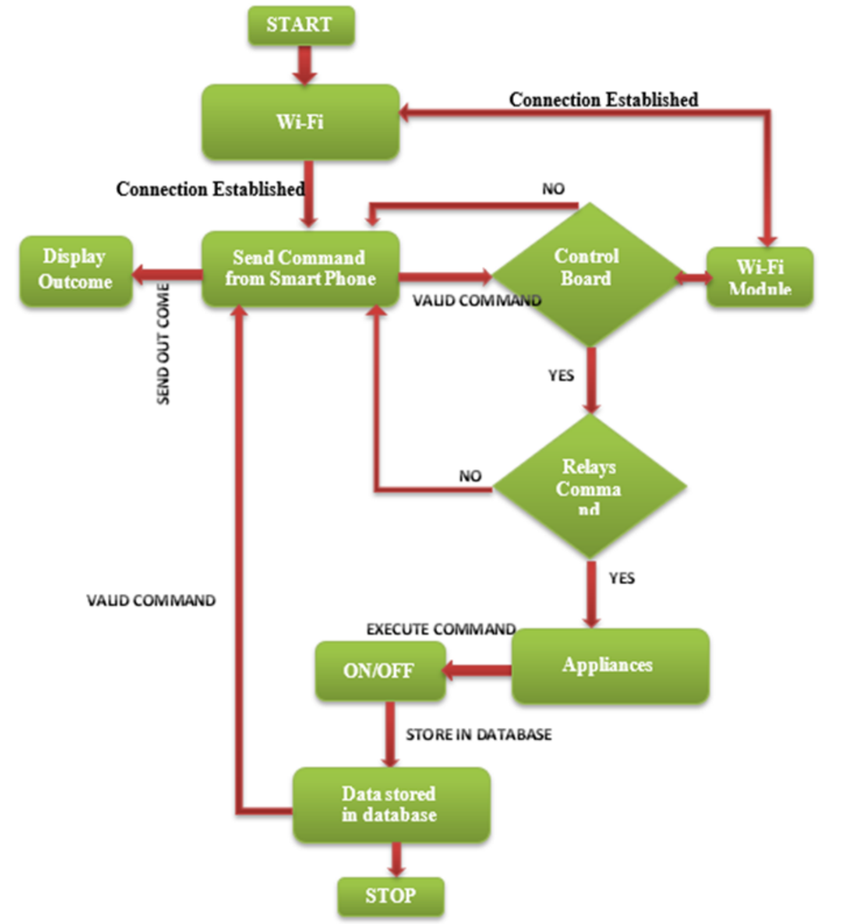


Figure 4-12 Flow Chart

Together in Excellence

4.11 Summary

The study aimed at building an effective and reliable android mobile-based controle system for smart homes using open sources. This chapter discussed the specifications, pin function descriptions and how the board, relays and Wi-Fi module are integrated. MIT App Inventor, firebase, Arduino IED, Proteus design suite were used to design and create the system's backend algorithm. The implementation and simulation results from the developed system are presented and discussed in the next chapter.

CHAPTER 5: IMPLEMENTATION AND RESULTS

5.1 Intoduction

This chapter presents a detailed account of the system' implementation and reports on the results. Section 5.1 outlines the major points of the implemented system and the functioning of different components and software applications used. Section 5.2 presents the results from the virtual terminal command simulation. Section 5.3 discusses the android mobile application' interfaces and gives the descriptions and command simulation of the system. Section 5.4 presents a performance analysis of the system by comparing it against two other approaches, the Bluetooth and the ZigBee. The summary of the chapter is given in section 5.5.

5.2 Implementation of the Home Automation System

The system was tested by simulation in two volleys. One was by using the Virtual Terminal command (VTC) and the second one was by using the android Mobile Application (AMApp). The android mobile phone was used as an input device, providing a user interface for remotely controlling the appliances. Firebase was used as a database for data storage and out of range data use. A Wi-Fi module (esp8266) was used to provide connectivity to the microcontroller (Arduino) since it is not built with Wi-Fi connectivity capacity. Arduino Uno Board was used as the controller receiving and issuing commands. Relays command was used to provide abilities to switch ON/OFF appliances, and finally bulbs were used as appliances behaving like outputs.

University of Fort Hare
Together in Excellence

Hardware / Software / Device	Description / Usage
Android Mobile Application	- Input device - Provide user interface - Gives command (switches ON/OFF) - Output device (display the state of each appliance in the system)
Firebase	- Provide data storage capability - Database software - Storage Application - Backend storage Service
Wi-Fi module (esp8266)	- Provide Wi-Fi connectivity to the controller
Arduino Uno	- Provide communications between the mobile application and appliances - Controller - Interpret commands for appliances

Relays	- Switches ON/OFF - Provide commend
Lights (bulbs)	- Output - Shows the state of appliances in the system on command

Table 5.15 brief description of devices

The switching On or Off of the appliances in the system were tested by simulation. After a successful test, the next stage of controlling the system using the android mobile application was implemented and tested.

5.3 Commands From a Virtual Terminal

As mentioned above, the first test was done using a virtual terminal command (cmd) to check the conditions for switching ON and OFF appliances in the smart home mobile-based control system. Figure 5-1 shows the simulated results of the outputs when switching ON/OFF appliances using the virtual terminal command in the Proteus design suit.

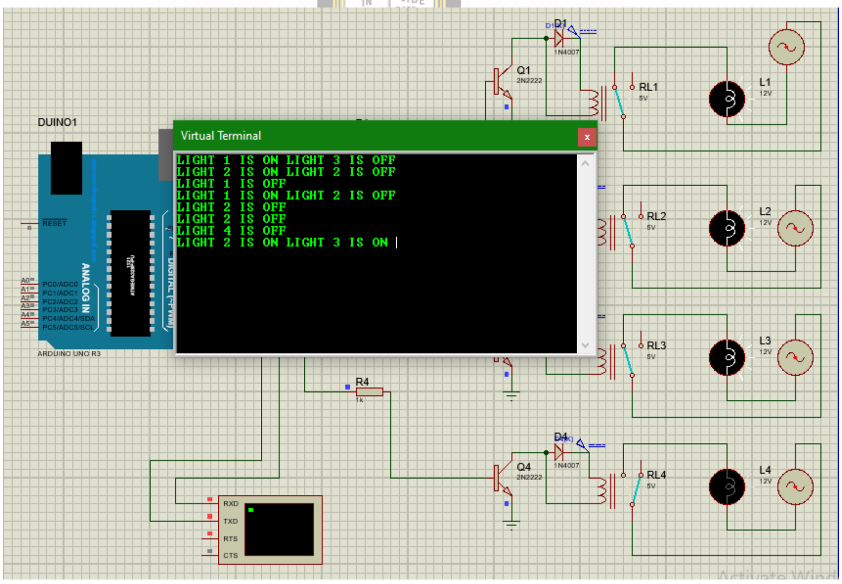


Figure 5-1 Command from a virtual terminal

Table 5.2 describes a clear command process for appliance control displayed in Figure 5-1.

The table shows five columns, with the first column "Device/load" display appliances used in the system, the second column shows the first commands placed from the virtual terminal and the third column displays responses from the first command. Command 2 column displays the second command from the virtual terminal. Each time the number "one" was pressed from the laptop keyboard "Light 1" was turned ON, by pressing the number "one" again from the keyboard "Light 1" was turned OFF. The same logic applied to Light 2, Light 3 and Light 4 respectively. Lastly by pressing the number "0" on the keyboard, all the lights can either be switched ON or OFF at the same time.

Device/load	Command 1	Response	Command 2	Response
Light_1 ON/OFF	1 is pressed	ON	1 is pressed again	OFF
Light_2 ON/OFF	2 is pressed	ON	2 is pressed again	OFF
Light_3 ON/OFF	3 is pressed	ON	3 is pressed again	OFF
Light_4 ON/OFF	4 is pressed	ON	4 is pressed again	OFF
All Light ON/OFF	0 is pressed	ON	0 is pressed again	OFF

Table 5.16 Command for appliances control from a virtual terminal

5.4 Commands from the Android Mobile Application

After a successful test of switching ON and OFF appliances using the virtual terminal command (VTC), the android mobile application was developed to achieve the system's purpose, which is allowing the control and command of any appliance in the system. The android mobile application from the android phone could select ON/OFF and gave a specific and distinct command to appliances in the smart home mobile-based control system. MIT App Inventor was used to interface and communicate with the Arduino Uno Board from an Android mobile application. The android mobile application has ten buttons that command appliances separately, whereby four buttons turn ON separate lights, the four other buttons turn them OFF, and the remaining two turns either all lights ON or OFF. The android mobile application is a very simple and user-friendly application. On any given command, the appliances in the system were turned ON or OFF by pressing any button shown in Figure 5-2 and Figure 5-3 (2 commands were shown, the procedure is similar to the rest). Table 5.3 shows the command for appliances control using the android mobile application.

University of Fort Hare

Figure 5-2 Mobile application user interface OFF stat

Figure 5-3 Mobile application user interface ON stat

The back-end codes of the android mobile application were designed in block coding which is stress-free from algorithm writing. As shown in Figure 5-4 and Figure 5-5, data (commands) was sent and saved to Firebase (database) using any given commands from the android mobile application. The command was later sent to the Arduino board command using the NodeMCU (esp8266) providing connectivity for the command board.

University of Fort Hare
Together in Excellence

Figure 5-5 Firebase database Appliances OFF

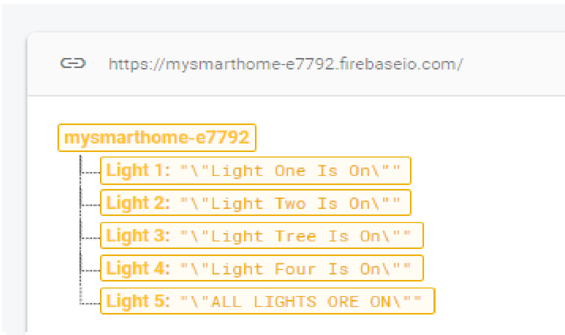


Figure 5-4 Firebase database Appliances ON

The block codes for the android mobile application were structured as shown in figure 5-6.

Figure 5-6 Block Codes for Android Mobile Application

After a successful connection between the microcontroller, Arduino Uno, and the Wi-Fi module (esp8266), commands were sent from the android mobile application. From the given commands, data was saved in the database. Signals were sent to the Wi-Fi module according to commands given from the mobile application to enable the microcontroller (Arduino command board) to process the given command. For example, when the Light 1 On button was pressed, the instruction was sent to the esp8266 via the internet, Firebase saved the data, and then the Wi-Fi module gave the input to the command board, telling the board to put on Light 1. In this manner, the communication between the android mobile application and the home system was achieved. Figure 5-7 shows the connection set-up and hardware interfacing.

University of Fort Hare
Together in Excellence

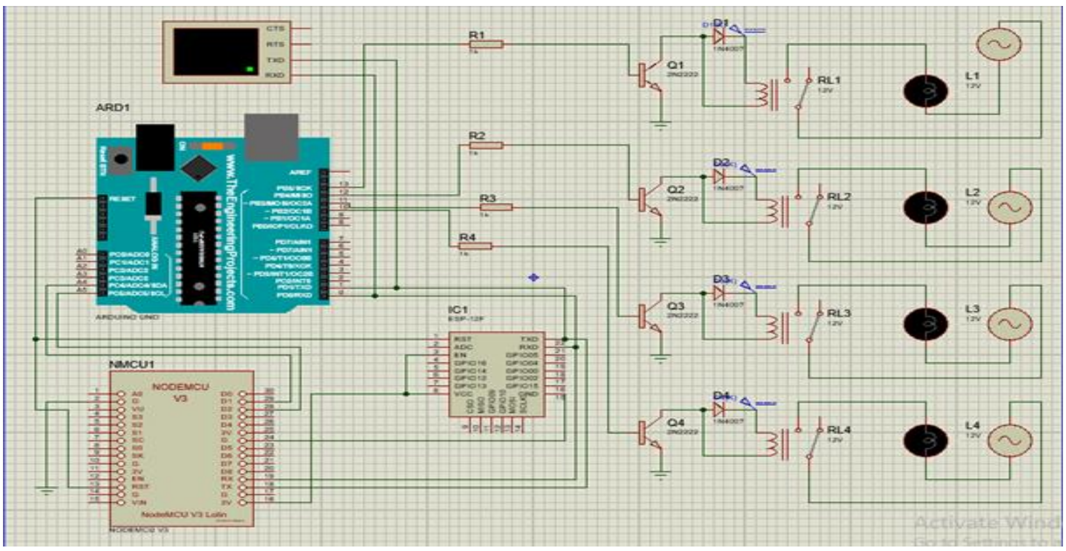


Figure 5-7 Final Implementation and simulation of the System

Table 5.3 shows the simulation command using the android mobile application to control appliances in a smart home system.

Device/load	Action 1	Out Come	Action 2	Out Come
Light_1 ON/OFF	Light1 On is pressed	ON	Light1 off is pressed	OFF
Light_2 ON/OFF	Light2 On is pressed	ON	Light2 off is pressed	OFF
Light_3 ON/OFF	Light3 On is pressed	ON	Light3 off is pressed	OFF
Light_4 ON/OFF	Light4 On is pressed	ON	Light4 off is pressed	OFF
All Light ON	On all lights Pressed	ON		
All Light OFF			Off all lights Pressed	OFF

Table 5.17 Command for appliances control (AMApp).

5.5 Results

5.5.1 Performance Analysis

University of Fort Hare
Together in Excellence

As part of analysing the performance of the developed system, the developed system was compared against two other approaches; the Bluetooth and the ZigBee. Figure 5-8 shows the performance results of the developed system versus Bluetooth and ZigBee. The primary vertical axes or the y-axes in Figure 5-8, display the number of failures. The secondary axes/ y-axes display the number of errors. The blue chart shows the number of failures of the developed system versus Bluetooth and ZigBee. Bluetooth system has four failures, ZigBee has three failures and the Wi-Fi system did not encounter any failures. The orange line shows errors of each system in percentage. With a 0% error, the developed system outperformed the Bluetooth with 8% error and ZigBee 6% error.

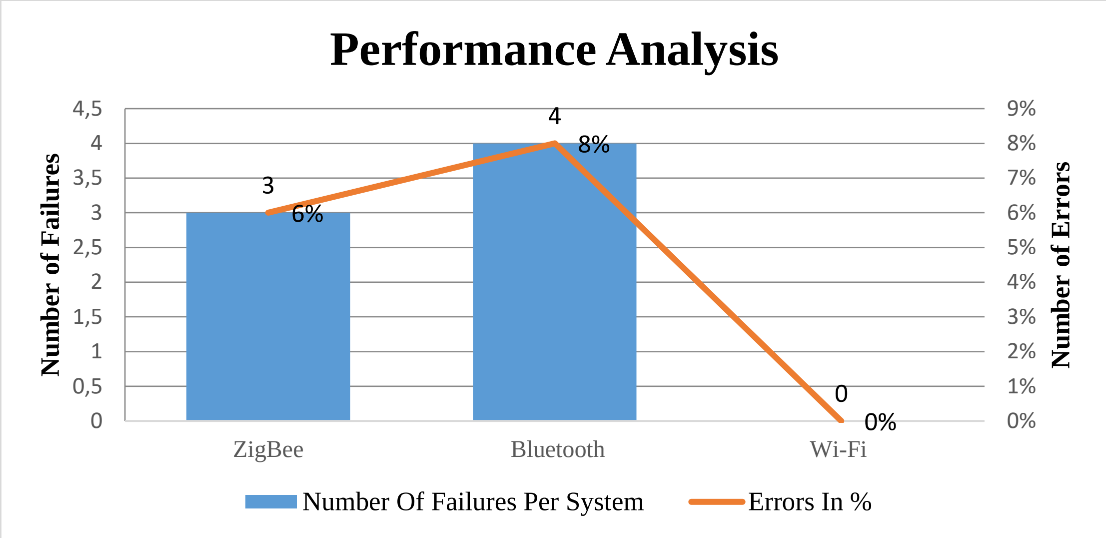


Figure 5-8 Performance analysis graph

5.5.2 Command from the same location

The time taken by home appliances to turn ON/OFF when controlled remotely using the android mobile application is presented in Figure 5-9. The primary vertical axis or the y-axis represent the time in seconds which is the response time of appliances after a command was processed, with a highest number of thirty-two seconds response time when turning on appliances and twenty seconds response time when switching off the lights. The x-axis or primary horizontal axis represent the number of ten trials conducted during the testing of the system. The blue line in the figure represents the time it took to switch on appliances. As shown in Figure 5-9, it took thirty-two seconds to turn on the lights from the first attempt, then twenty seconds for the second attempt, and so on up to the tenth attempt as shown in Figure 5-9. Similarly, the orange line shows how long it took to switch off appliances for each trial.

University of Fort Hare
Together in Excellence

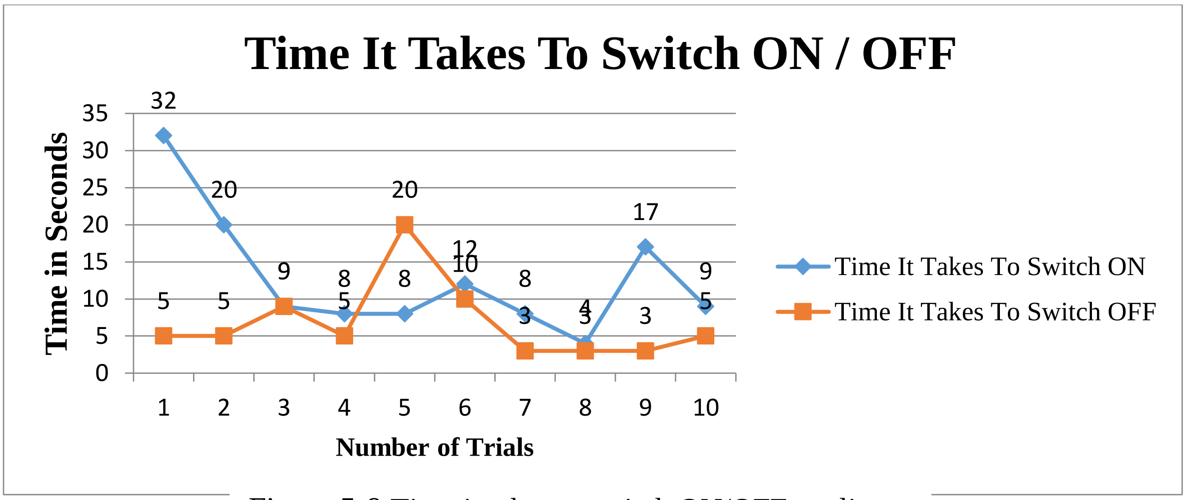


Figure 5-9 Time it takes to switch ON/OFF appliance

5.5.3 Command from a different location

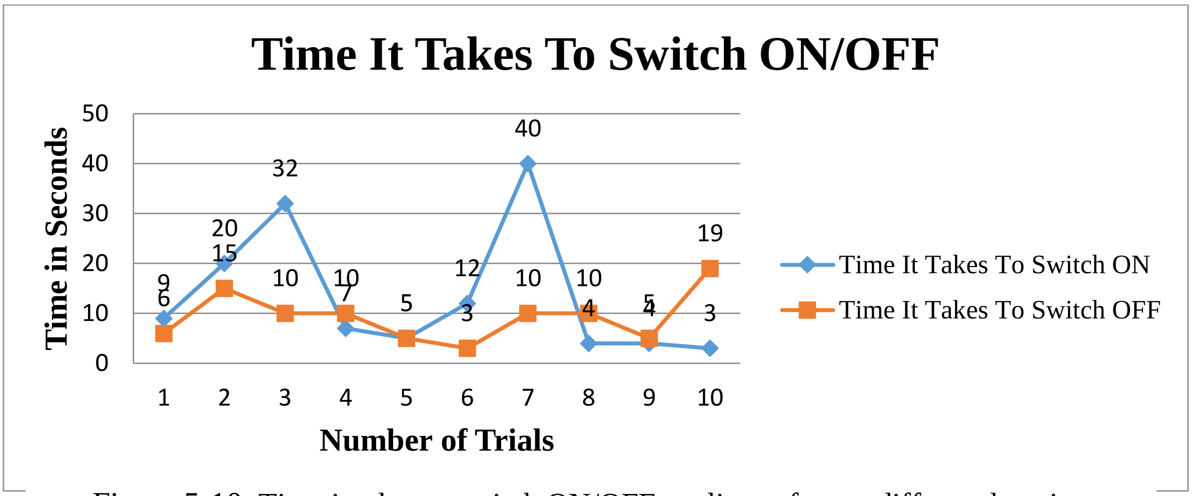


Figure 5-10 Time it takes to switch ON/OFF appliance from a different location

Just as mentioned in section 5.4.1, ten trials were conducted to determine the time interval taken by home appliances to turn ON/OFF when controlled remotely using the android mobile application from a different location.

As shown in Figure 5-10, the primary vertical axis or the y-axis represents the response time of appliances after a command was processed. The figure shows that it took forty seconds response time when turning on appliances and nineteen seconds response time when switching off the lights. The x-axis or primary horizontal axis represents the number of trials conducted during the testing of the system from a different location. The blue line in the figure represents the time it took to switch on appliances. It took nine seconds to turn on the lights from the first attempt, then twenty seconds for the second attempt, and so on up to the tenth attempt, which took three seconds for the lights to go on as shown in Figure 5-9. Similarly, the orange line shows how long it took to switch off appliances for each trial.

University of Fort Hare
Together in Excellence

5.5.4 Reliability

The mean time to failure (MTTF) also known as maintenance metric or lifespan of an asset, indicates how long it takes for an unrepairable asset to cease operating before it fails. MTTF was used to determine the reliability of the developed mobile-based control system.

Let, $\text{MTTF} = \frac{T_h}{T_a}$

With: $-$ $\boldsymbol{MTTF}$ mean time to failure ($hours$).

$- \boldsymbol{T_h}$ Total hours of operation $(hours)$.

$- \boldsymbol{T_a}\ Total\ assets\ in\ use.$

Knowing the total numbers of assets in use in our system, $\boldsymbol{T_a} = \mathbf{18}$ and the total hours of operation $\boldsymbol{T_h} = \mathbf{186}\ hours$

So, $\boxed{MTTF = \frac{186}{18} = 10.3\ hours}$, Therefore, the average amount of time of an operating asset before it fails in a month will be 10.3 hours for 6 hours operation, and for a 24 hours operation, the average will be 41.3 hours before the asset fails.

therefore, $\boxed{MTTF = \frac{744}{18} = 41.3\ hours}$

An asset will typically operate for 121.6 hours before failing in a year and for 6 hours operation, $\boxed{MTTF = \frac{2190}{18} = 121.6\ hours.}$

And for a 24 hours' operation, the average will be 486.6 hours before the asset fails,

$\boxed{MTTF = \frac{8760}{18} = 486.6\ hours.}$

The reliability results show the average lifespan of assets in the system before they fail. Knowing the lifespan of an asset before it fails can help in reducing downtime of the system by planning or scheduling maintenance and develop an improved maintenance strategy. As part of the reliability equation for the system, calculating the mean time to failure is essential. It is more beneficial to anticipate when assets will malfunction and to replace them before they fail. This reduces the need for costly repairs, minimizes system downtime, and will extend the lifespan of the components when individual assets fail.

University of Fort Hare
Together in Excellence

5.6 Summary

This chapter presented the system' implementation and reported on the results. For testing, the system used two approaches. One was by using the virtual terminal command, for testing the condition of switching on and off appliances. The second was by using the android Mobile Application (AMApp) to fully control and monitor the system. The developed system was compared with two other similar systems; the Bluetooth and the ZigBee. The results revealed that the developed system has the best performance. The developed system produced 0% error, while the Bluetooth had 8% error and ZigBee 6% error. Reliability of the systems was also tested. To do so, the mean time to failure was used to determine the lifespan of an asset in the system before it fails. From the results, we can indeed say, a reliable system was designed and successfully implemented to controls remotely home appliances. The system depends on the Wi-Fi network to operate the commands between the phone application and the developed system. The system used a Wi-Fi module, mobile phone Android-based application, cloud storage, Arduino Uno board, relays, android application, and appliances. Any android mobile phone supporting the Wi-Fi connection can be used in the system. One important point, is that the user can control the system from anywhere which also has the advantage of low cost and flexible control by means of Android-based smartphone. Just by connecting to a Wi-Fi network, this can be accomplished. If the Wi-Fi is unavailable, mobile networks, like 3G or 4G, could provide an alternative method to connect to the system.

University of Fort Hare
Together in Excellence

CHAPTER 6: CONCLUSIONS AND FUTURE WORKS

6.1 Introduction

This chapter concludes the study. The chapter is structured as follows: Section 6.2 gives a summary of the study. In Section 6.3, the extent to which the study achieved its objectives is presented through dissecting each study objective. The study's contributions are presented in Section 6.4. Finally, the future work is presented in section 6.5.

6.2 Research Summary

The aim of the study was to develop and analyse the reliability of a mobile-based home automation system. Chapter one presented the rationale of the study and set out the desired goals. Chapter two presented a theoretical framework where relevant concepts like home automation, Bluetooth, Wi-Fi, ZigBee, Machine Learning, Deep Learning, Reinforcement Learning, Deep Reinforcement Learning and the Internet of things were discussed. In chapter three, the methods and procedures used during the course of the study are discussed. The study used meta-analysis, a variant of systematic literature review approach for reviewing literature. For developing the home automation system, the Waterfall model approach was used. A simulation methodology was used for testing the system's reliability and usefulness. The system architecture is presented in chapter four. Various components of the system were also identified and their interaction explained. Chapter five presented the implementation of the home automation system and also presented the results analysis. The system's performance was compared with the Bluetooth and ZigBee systems.

University of Fort Hare
Together in Excellence

6.3 Revisiting the study objectives

Objectives 1:

To determine the techniques used for the development of smart home control systems.

Through literature review, different wireless technologies commonly used in developing smart home systems were identified and discussed. The search, collection and selection for relevant articles was also explained. Methods used with smart home such as, Machine Learning, Deep Learning, Reinforcement Learning, Deep Reinforcement Learning were discussed to have a better understanding on smart homes. The technologies discussed are the ZigBee, Bluetooth, and Wi-Fi. A number of parameters were used in discussing the technologies. The parameters discussed are the data rates, the ranges, the frequencies and the network sizes for the technologies. Diverse methods that make a home to be smart were reviewed. The methods discussed are Machine Learning, Deep Learning, Reinforcement Learning, Deep Reinforcement Learning. This information was presented in chapter two.

Objective 2:

To identify technologies used for implementing home automation systems.

In chapter three, the methods and techniques used for developing the home automation system were presented and explained. The study also reviewed literature of smart home incorporated with AI and Machine Learning. For reviewing the literature, the study used systematic literature review methodology to understand and to learn what other researchers have done. For implementation, the study used waterfall model as a methodology. For system evaluation, the study applied simulation methodology. Key issues that were also discussed include the design, implementation and simulation of the system.

Objective 3:

To design a home automation system based on Android.

The system architecture was presented in chapter four thereby showing the system design. The chapter also discussed the specifications, pin function descriptions and how the board, relays and Wi-Fi module are integrated. MIT App Inventor, firebase, Arduino IED, Proteus design suite were used to design and create the system's backend algorithm.

University of Fort Hare
Together in Excellence

Objective 4:

To evaluate the performance and reliability of the developed mobile-based smart home control system.

To achieve the above objective, a reliability of the systems was tested. To do so, the mean time to failure was used to determine the lifespan of an asset in the system before it fails. From the results, it was noted that the system is reliable. The system depends on the Wi-Fi network to operate the commands between the phone application and the developed system. The system used a Wi-Fi module, mobile phone Android-based application, cloud storage, Arduino Uno board, relays, android application, and appliances. As part of performance analyses of the study' system, the developed system was compared against two other approaches; the Bluetooth and the ZigBee. The developed system was found to have outperformed the two other approaches during the evaluation process.

6.4 Study's contributions

The study contributes to the body of knowledge by discussing technologies for implementing home automation system and designing the system. The implemented system and its testing demonstrate how open source tools can be used to build inexpensive home automation systems. The results of the study on reliability analysis can also contribute insights to for designing maintenance strategies for home automation systems.

6.5 Recommendation and Future works

The system prototype was designed be simple, low cost and easy to use. Nevertheless, the system still requires more expansion and improvement in terms of the functionality. The system can be technologically advanced for platforms other than android system. SMS system can be incorporated for remote communication, Perfections can be made by integrating power consumption monitoring facilities and saving mode for power consumption. The recommendation includes voice control or speech recognition mode. Voice commands can be integrated so that people with hands disability or vision problem can also be able to operate the system, etc.

University of Fort Hare
Together in Excellence

REFERENCES

[1] Stats SA report, 2011. “Profile of persons with disabilities in South Africa”, http://www.statssa.gov.za/publications/Report-03-01-59/Report-03-01-592011.pdf

[2] M. Yan and H. Shi, ―Smart Living Using Bluetooth-Based Android Smart Phone, Int. J. Wirel. Mob. Networks, vol. 5, no. 1, pp. 65–72, 2013.

[3] R. Piyare and S. R. Lee, ―Smart Home-Control and Monitoring System Using Smart Phone, Department of Information Electronics Engineering, Mokpo National University Mokpo 534-729, South Korea, in 1st International Conference on Convergence and its Applications, 2013.

[4] https://whatis.techtarget.com/definition/sensor

[5] Nordrum, A. (2016, August 18). Popular Internet of Things Forecast of 50 Billion Devices by 2020 Is Outdated. Retrieved April 14, 2018, from https://spectrum.ieee.org/tech-talk/telecom/internet/popular-internet-of-things-forecast-of-50-billion-devices-by-2020-is-outdated

[6] Li, R. Y., Li, H. C., Mak, C. K., & Tang, T. B. (2016). Sustainable Smart Home and Home Automation: Big Data Analytics Approach. *International Journal of Smart Home,10*(8), 177-198. doi:10.14257/ijsh.2016.10.8.18

[7] Can we use this circuit to prevent going flyback to the supply line? (n.d.). April 14, 2018, from https://forum.allaboutcircuits.com/threads/can-we-use-this-circuit-to-prevent-going-flyback-to-supply-line.126791/

[8] The history and future of the internet – itransition – 25.11.2019 | Sandra of things, from https://www.itransition.com/blog/iot-history

[9]https://www.sciencedirect.com/science/article/pii/S2542660518300477?casa_token=MRm1HxxkRvgAAAAA:TD0PSa7OkwuH0gz3qPoPQGWnmL-wVpSL5v83EMrCc4mvVcXR9uO3mnYdQzr_5uY2A5WTyUJ3Z8s

[10] Alan Bensky, in Short-range Wireless Communication (Third Edition), 2019. Personal Area Network, from https://www.sciencedirect.com/topics/engineering/personal-area-network

[11] Manish Shrivastava, Donart A Ngarambe, in Proceedings from the International Conference on Advances in Engineering and Technology, 2006, from https://www.sciencedirect.com/topics/engineering/personal-area-network

[12] Pocket-lint, What is ZigBee, and is it important for your smart home? https://www.pocket-lint.com/smart-home/news/129857-what-is-the-zigbee-and-why-is-it-important-for-your-smart-home

[13] Multi-Hop Networking, Research in wireless communication and signal processing, Professor Robert W. Heart Jr. https://www.profheath.org/research/multi-hop-networking/

[14] Arduino Uno Rev3, 2021, Arduino https://www.store.arduino.cc/arduino-uno-rev3

[15] Components101 microcontrollers Arduino Uno, February 28, 2018, from https://www.components101.com/microcontrollers/arduino-uno

[16] Electronics hub esp8266-arduino-interface, December 13, 2017, from https://www.electronicshub.org/esp8266-arduino-interface

University of Fort Hare
Together in Excellence

[17] ESP-12F Wi-Fi Module V1, Ai-Thinker, 2018, from
https://www.waveshare.com/w/upload/a/a0/ESP-12F-datasheets.pdf

[18] Micro robotics ESP-12F, Wi-Fi module, 2021
https://www.robotics.org.za/ESP-12F

[19] Home Automation System, Wi-Fi-based home automation system using cell phones, 4, July – Aug 2019

[20] Wikipedia. (2012, 12th December). *Home automation*. Available:
http://en.wikipedia.org/wiki/Home_automation

[21] https://www.elprocus.com/different-types-of-automation-systems/

[22] https://www.britannica.com/technology/automation/Robots-in-manufacturing.

[23] P.CHAHUARA QUISPE, "Contrôle intelligente de la domotique à partir d'informations temporelles multi sources imprécises et incertaines", thèse de doctorat Laboratoire d'informatique de Grenoble (LIG) et d'Ecole Doctorale Mathématiques, Sciences et Technologies de l'information, Informatique, 2003.

[24] Mabrouk. A, M'hid.S, "Conception et réalisation d'une Maison intelligente ", RAPPORT DE FIN D'ETUDES Pour l'obtention du diplôme LICENCE en Génie Electrique, UNIVERSITE SIDI MOHAMMED BEN ABDELLAH FACULTE DES SCIENCES ET TECHNIQUES FES, 2018.

[25] Certificate Security for IoT Devices
https://ww.securew2.com/blog/certificate-security-for-iot-devices

[26] "Climate in South Africa." Worlddata.info, Retrieved February 20, 2021, from,
https://www.worlddata.info/africa/south-africa/sunset.php

[27] postscapes /internet of things iot-history, 11 December 2019, from,
https://www.postscapes.com/iot-history/

[28] krakul /iot-trends to ecpect in 2021, Dec 18, from, https://krakul.eu/iot-trends-to-expect/

[29] Cisco Global 2021 Forecast Highlights, 2016, from,
https://www.cisco.com/c/dam/m/en_us/solutions/service-provider/vni-forecast-highlights/pdf/Global_2021_Forecast_Highlights.pdf

[30] Compare the cloud, 2018, from.

[31] Appsforagro Impact of IoT in the agriculture, from,
https://www.appsforagri.com/en/news/impact-of-iot-in-the-agriculture/

[32] how-increase-water-supply-efficiency-artificial-intelligence, November 2020

[33] *(10) (PDF) Design and Implementation of a WiFi Based Home Automation System*. Available from: https://www.researchgate.net/publication/230883124 Design and Implementation of a WiFi Based Home Automation System

[34] https://www.quora.com/What-is-the-advantage-of-using-bluetooth-for-home-automation

[35] https://www.bluetooth.com/blog/the-importance-of-interoperability-in-the-smart-home/

[36] A Survey on Various Home Automation System and Security, Selva Priya B[1], Geethamani R[2] *[1,2]EEE Department, Sri Krishna College Of Engineering and Technology*

[37] Dechuan Chen and MeifangWabg,(2006) "A home security ZigBee network for remote monitoring application", Proceedings of IET International Conference on Wireless, Mobile, and Multimedia Networks", November 6-9, Hangzhou, China, pp. 1-4

University of Fort Hare
Together in Excellence

[38] V. Sathya Narayanan1 and S. Gayathri, "Design of Wireless Home automation and security system using PIC Microcontroller", International Journal of Computer Applications in Engineering Sciences, Vol. 3, special issue, pp. 135-140

[39] Woo-Choo Park and Myung-Hyun Yoon, (2006)" The Implementation of Indoor Location System to Control ZigBee Home Network", Proceedings of International Joint Conference SICR-ICASE", October 18-21, Busan, South Korea, pp. 2158-2161

[40] Chunglong Zhang, Min Zhang, Young Sheng Su, and Weillian Wang, (2012) " Smart home design based on ZigBee wireless sensor network", Proceedings of the 7th International ICST Conference on Communications and networking, Kun Ming, pp. 463-466

[41] Jui-Yu Chang, Tao-Yuan, Min-Hsing Hung, and Yen-Wei Chang, (2007) "A ZigBee based Power Monitoring System with Direct Load Control Capabilities", Proceedings of IEEE International Conference on Networking, Sensing, and Control, April 15-17, London, 2007, pp. 895-900

[42] Karia Deepak, JaypalBavisker, Raj Makwana and PanchatNiraj,(2013) " Performance analysis of ZigBee based load control and power monitoring system", Proceedings of the InternationalConference on Advances in Computing, Communications, and Informatics, Myshore, August 25, 2013, pp. 1779- 1484.

[43] Jieming Zhu, Xuecai, Yucang Yang, and Hang Li, (2010)" Developing a voice control system for ZigBee based home automation", Proceedings of IEEE International Conference on Network Infrastructure and Digital Content, September 24-26, Beijing, 2010, pp. 7737-741
[44] Y.Usha Devi,(2012) "Wireless Home Automation System Using ZigBee", International Journal of Scientific & Engineering Research, Volume 3, Issue 8, August 2012, pp. 1-5
[45] Circuits today Proteus PCB Design and Simulation Software – Introduction, from https://www.circuitstoday.com/proteus-software-introduction

[46] The Engineering Knowledge Introduction to proteus, from https://www.theengineeringknowledge.com/introduction-to-proteus/
[47] Educative Edpresso What Is Firebase? From, https://www.educative.io/edpresso/what-is-firebase
[48] Smart Home Automation System using Android Application, April 2017
[49] Statista IoT Number Of Connected Devices Worldwide, Lionel Sujay Valishery, Jan 22, 2021, from, https://www.statista.com/statistics/1101442/iot-number-of-connected-devices-worlwide/
[50] IoT and non-IoT Connections worldwide 2010-2025, Lionel Sujay Valishery, March 8, 2021, from, https://www.statista.com/statistics/802690/woldwide-connected-devices-by-access-technology/

University of Fort Hare
Together in Excellence

[51] Designing a Smart Home Management System with Artificial Intelligence & Machine Learning, March 2021, Mehmet Mücahit KAYA
[52] Artificial-Intelligence-In-Agriculture-Using-Modern-Day-Ai-To-Solve-Traditional-Farming-Problems, Pravar Jain — November 4, 2020
[53] Ai-And-Machine-Learning-The-Relationship-Explained, Regenesys Business School, September 9, 2020
[54] Bini, S., 2018. Artificial Intelligence, Machine Learning, Deep Learning, and Cognitive
[55] Machine Learning, what is it and what it matters, what are some popular machine learning methods? SAS Institute, 2021
[56] Tutorialspoint, 2020, Machine Learning
[57] Sas, 2018. What is deep learning?. [Online]
[58] Early Detection System for Gas Leakage and Fire in Smart Home Using Machine Learning, Lamine Salhi†, Thomas Silverston††, Taku Yamazaki†††, and Takumi Miyoshi†††, †Graduate School of Engineering and Science, Shibaura Institute of Technology, Saitama, Japan
[59] Smart Home System Based on Deep Learning Algorithm, Yanfei Peng *et al* 2019 *J. Phys.: Conf. Ser*. **1187** 032086
[60] Voice-Activated Smart Home Controller Using Machine Learning LEANDRO FILIPE 1,2, RICARDO SILVA PERES 1,2, (Member, IEEE), AND RUI MANUEL TAVARES1,2, (Member, IEEE) 1Department of Electrical and Computer Engineering, NOVA School of Science & Technology, NOVA University of Lisbon, 2829-516 Caparica, Portugal 2UNINOVA_Centre of Technology and Systems (CTS), 2829-516 Caparica, Portugal Corresponding author: Ricardo Silva Peres, 2021
[61] Erol, Y., Balik, H. H., Inal, S., & Karabulut, D. Safe and secure PIC based remote control application for intelligent home. IJCSNS International Journa of Computer Science and Network Security, 2007, 7(5), pp.179-182.

University of Fort Hare
Together in Excellence